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By courtesy of the *American Museum Journal* By Carl E. Akeley

"The Wounded Comrade."

To be a specialist means, to be able to do more things well, and one thing much better than the common run of men. Mr. Akeley is a specialist. He combines rare qulities and extensive experience as an observer of animals, with the artist's skill in designing animal groups. His work figures prominently in American Museums; and he is at the present time engaged upon the preparation of a group of elephants for the American Museum of Natural History. In addition to the main life size group, there will be a number of miniature groups or single figures cast in bronze. One of these bronze groups is shown on this page. A glance suffices to show that we have before us not merely a "museum specimen" to illustrate a phase of animal life, but a true art production, a fine piece of statuary.

Human life is full enough of commonplace, of the petty drudgery incidental to the quest of food and shelter. This is naturally still more true in the case of animals, who have not risen to the same mental and moral plane as man. Yet even among them there are not lacking, as everybody knows, affecting instances of devotion and "higher mental qualities." The elephant in particular, that huge and seemingly unwieldy pachyderm, is noted for the high development of his mental faculties. The group which Mr. Akeley has entitled "The Wounded Comrade" brings before our mind a touch of pathos from the jungle, a reminder that the human heart does not alone harbor feelings of altruism and devotion.

ART IN NATURAL HISTORY.—[See page 189.]

Insects That Carry Disease*

Insidious and Elusive Foes of Man

By Charles Dury

THE newspapers contain frequent warnings to housekeepers to be sure and "swat the first flies." They don't tell what kind of flies to swat, for, be it remembered, there are flies and flies; something like 10,000 species in America, north of Mexico. It is to be presumed the papers refer to the "house-fly," *Musca domestica*, or the "stable-fly," *Stomoxys calcitrans*, both of which are legitimate game to "swat." Not that swatting in this way will do much good; but people do so love to swat something; it is an ancestral trait. It would be much better to "swat" the breeding-places of these two species. In that way something can be accomplished. There are some small tachine flies, that so resemble house and stable flies in appearance superficially, that it takes an expert to distinguish between them. Yet, in habits they are absolutely different. The tachina flies devote their lives to the destruction of various lepidopterous and other larvæ, many of them the most injurious kinds. They destroy these larvæ by depositing their eggs on the body of the larva. In destroying the breeding-places of house and stable flies, none of the tachina flies would be harmed, as they do not frequent such places. I mention these facts to show that only a very limited number of species of flies are injurious, and that many other species are the most valuable of living creatures.

According to some of the newspapers, the house-fly's sole purpose in life is to gather up an assortment of disease germs, and deposit them on our food, malignant typhoid fever being their specialty, and they doubtless deserve the reputation they have so recently acquired.

In former years, in the discussion of the habits and merits of the house-fly, I have heard it stated that they were useful as scavengers. At that time it was not even suspected that they had played so important a part as disease carriers. After many years' study of insects under normal conditions, I have failed to find any benefit or value in the house-fly, aside from its being the faithful ally of the doctor and undertaker.

The house-fly does not bite, its proboscis being soft and fleshy. It does not require a biting insect to infect one with bacterial diseases, as it does in the case of malaria and yellow fever, whose parasitic organisms are protozoans, which are conveyed and introduced into the blood of a non-infected person by the bite of certain mosquitoes. The automobile has done much to help in the control of the house-fly. While it is liable to slip up on you with its "gum-shoes," and knock you before you can escape, yet it has largely displaced the horse, and, with the passing of the horse, the manure-pile, the most prolific breeding-place of flies, is also gone. Warmth and moisture are two requisites in the rapid breeding of house-flies. The stable-fly breeds in similar filth with the house-fly; but, unlike the house-fly, it is a savage biter. I have heard persons exclaim: "My! how the flies bite; it must be going to rain!" thinking they had been bitten by a house-fly, as the two species look so very much alike.

The stable-fly is suspected of being a carrier of infantile paralysis. The investigations of Brues and Rosenau point strongly in that direction. The stable-fly is, therefore, a very dangerous and undesirable invader of the home.

Another small fly that should be looked on with suspicion is the little *Drosophial*, or "fruit-fly." It breeds in human and other excrement, and, in country places, may walk over the excreta of a typhoid patient, and then fly directly to and alight on the fruits and vegetables, leaving bacteria wherever it goes. It is particularly attracted to over-ripe fruits, and those that are beginning to ferment and decay. In clean and well-sewered cities, where the excreta of the sick are well disinfected and destroyed, the danger of infection by house-flies is reduced to a minimum. Consumptives who spit bacilli-laden sputum in the streets are a menace. The house-fly is attracted instantly to such matter.

If flies invade the home, they can be driven out by making the room dark, leaving one opening through which light can enter. The flies will fly to the light and exit. This is better than swatting or mashing them, and knocking the bacteria off into the room, to be breathed or eaten by the inmates. See that the fly-screens are tightly fitted, and in place not later than May 1st, where they should remain until November. With the house-fly an ounce of prevention is worth many pounds of cure.

SPOTTED FEVER.—TICK DERMACENTOR VENUSTUS.

A young man from Cincinnati wished to locate in the West, and made a trip of inspection, visiting Montana, Washington, Oregon, California, and New Mexico. He was very much impressed with the Bitter Root Valley, Montana. But he was warned by disinterested persons that there was a deadly disease there that very frequently proved fatal, and that the disease was caused by the bite of a tick, *Dermacentor venustus*. In view of this alarming condition, and notwithstanding the fertile and climatic advantages of the valley, he did not invest any money nor locate there. The mortality from this disease, called spotted fever, is given at 70 per cent. In 400 cases reported, 280 died.

The following facts should be noted:

1. Ticks infested with this disease are found in nature.

2. Adult ticks are able to acquire the disease by biting an infected animal, and to transmit it through the egg stage to the succeeding generation.

3. That certain mammals, including man, are susceptible to spotted fever.

4. To be able to develop eggs, the female must first become engorged with blood of some mammal. These facts have been abundantly proven by a series of experiments. While it is true that in the immature stage the tick feeds on the blood of the smaller wild mammals, in the adult stage they almost invariably feed on the large domestic mammals. Messrs. Hunter and Bishopp have shown that if the cattle are dipped in a solution of sodium carbonate, arsenic tri-oxide, pine-tar and water for three successive years, these ticks can be exterminated in this valley, and, in addition, it is desirable to exterminate as far as possible the smaller rodents and other mammals, which are a serious pest to agriculture, aside from the fact that they at times harbor larval ticks.

In Middle Park, Col., the chipmunks were so destructive at the time I made a visit there that nothing could be grown. An old ranchman told me that while he was planting a row of beans, the ground-squirrels were digging up his seeds while he was at the other end of the row, and this abundance of these animals prevails over much of the West.

To the biologist, the most interesting feature of this problem is: Why is this disease so deadly in the Bitter Root Valley, and so mild comparatively in other localities where the fever tick occurs, and what is the danger and likelihood of the virulent form of the disease spreading to other localities by the moving of cattle that might carry the ticks with them? It has been estimated that the diesase can be eradicated by arsenating the cattle, as mentioned above, and at a cost of $23,692 for the Bitter Root Valley, and specifications are given by Messrs. Hunter and Bishopp how this can be done.

YELLOW FEVER AND MALARIAL MOSQUITOES.

Some years ago a river steamboat, plying on the river from New Orleans to points as far up the Ohio River as Cincinnati and above, left New Orleans during one of the frequently recurring epidemics of yellow fever that had for years scourged that city. On the way up, and when near this city, some cases of yellow fever developed. The health authorities would not allow the boat to land, and compelled it to go up the river, fearing contact with these patients, and a spread of the disease here. There was a considerable scare at the time. The condition of the passengers and crew of the boat was most distressing. They were not allowed to land anywhere, and could not secure necessary articles for their use. At that time there was a total misconception of the method by which this fearful disease was transmitted from one person to another. It is perhaps well known to all medical men how the discovery was made that this disease could only be transmitted by the bite of mosquitoes of one species, *Ædes calopus*, and that this mosquito must first be inoculated by biting someone afflicted with the disease. You no doubt remember the work that was done in Cuba and elsewhere to prove these conclusions. How these most courageous and devoted students worked at the risk of their lives, and, in some cases, died in the work. How they used the garments and slept under bedding that had been taken from patients who had died of the disease in its most malignant form, to prove that the disease could not be contracted by contact. For several years the entomologists of the U. S. Department of Agriculture have been making a survey of the more southern and central parts of the United States to ascertain the exact geographical distribution of the yellow-fever mosquito. In 1905 an agent of the department called to see me, and examine the collections of diptera I had made here, to see if this mosquito was among them; but it was not. He was unable to find the species here. The nearest points to Cincinnati that he did find them were Frankfort and Louisville, Ky. He urged me to continue the search at a later date, so as to cover a greater range of territory and seasonal conditions. I started at Anderson's Ferry to the west of the city and investigated numerous points around the city as far east as Linwood. I made a careful search of the favorable places along the Ohio River, such as blacksmiths' shops where there were water-tubs seldom used, the cellars of fruit-houses where bunches of bananas were hanging, the holds of river steamboats, etc., but not one specimen could I find. Since then I have carried on the search, and though hundreds of mosquitoes were captured and examined, a number of species among them, not one *Ædes calopus* was there. While this is not conclusive, it would rather indicate that Cincinnati is not within the limits of distribution of this species. In this mosquito search I found malarial mosquitoes, *Anopheles punctipennis*, in great abundance; this is a rather large, dark-colored mosquito, with the wings strongly maculate with blackish spots. This mosquito again calls to mind conditions that prevailed here years ago when malaria, then called "chills and fever," "ague," or "shakes," was a common disease around Cincinnati and across the river in Kentucky. Many people had it every fall, so they rather became used to it. The quinine bottle stood on the mantelpiece with a spoon alongside. It went without saying, "Help yourself if you've got the shakes," and wash it down with a little corn whisky.

When we got our first fly-screens, nearly thirty years ago, I was peevish, because it prevented my getting the fine specimens of insects that came into the house, attracted by the light in the evenings. My companion in disappointment was the family cat, who was my competitor in securing the choice beetles that were then shut out.

As is well known, the organisms conveyed by anopheles, which are the germs of malaria, belong to the group of minute animals known as *protozoa*, and the germ of yellow fever and spotted fever also belong to the same class of parasitic organism. The malarial germ must first pass through the body of the mosquito before it reaches its complete development. The bite of anopheles is no worse than the bite of any other harmless mosquito, unless it is infected with germs secured from a malarial person. While I have frequently been bitten by this mosquito, I have never had malaria; either they were not infected, or I was not in a receptive condition.

In the American Museum of Natural History in New York there is an enlarged series of models which show anopheles and the malarial germs in a most beautiful manner, and one can see at a glance how the thing is done. The study of the lower forms of animal life is filled with such fascinating interest, and is of such importance, that one wonders why it is so neglected, and why so few otherwise well-informed persons are unable to distinguish their friends from their foes, even in the insect world.

CHIGGERS OR TROMBIDIUM—LEPTUS IRRITANS.

Forty years ago I never met with this pest in the vicinity of Cincinnati, although at that time I was doing a good deal of field work in collecting insects and other objects of natural history. In sweeping weeds and grasses, and beating the foliage of trees into net and umbrella,

*Read before the Science Club, University of Cincinnati.

I must certainly have encountered them if they had been here. About twelve years ago I first began to notice their presence in certain localities. Now they have spread nearly everywhere, and are particularly abundant in briary thickets. This is a serious calamity. How the thing has been introduced, or if always present, what has caused it to spread and become such a pest, would be interesting to know. They are excessively minute, being scarcely visible to the unassisted eye. Their life history has not been completely worked out, but it is supposed they are the larval form of one of the mites, hence the name sometimes given them of "harvest mite." Their method of attack is as follows: They crawl out on the tips of grasses or leaves, and remain in wait for some warm-blooded mammal to pass by, when they reach out with their forelegs and attach themselves to clothing or hair. If it is a man on to which they have secured a foothold, they crawl under the clothing and get to the skin, where they enter the sweat-pores, setting up a severe irritation with intense itching. The skin is red around the point attacked. In a few days a small pustule forms, and the dead mite is expelled by the discharge of the pustule. The supposition is that the irritating fluid of the mite is acid, hence the selection of some alkaline remedy. Ammonia in some form is often used. Soda also has a good effect. In the South they use a piece of fat salt bacon, which is rubbed over the part affected. Where there is much spreading of the inflammation, an antiseptic treatment is good, such as borax, peroxide of hydrogen, etc. But prevention, that most potent of all remedies, is to be recommended. A friend in New Jersey tells me before going out he wets his skin with a solution of washing-soda and allows it to dry on the skin. Another precaution is to use some strong-smelling essence, such as pennyroyal or peppermint, which acts as a repellant as long as the odor lasts. This is to be applied to clothing around the ankles, waist, and neck, just before exposure. Naphthaline is also a good repellant. These mites are a six-legged creature in the "shigger" stage; but when they reach maturity they acquire an additional pair of legs.

This species is not the "chigger" or "chigoe" of the tropical parts of South America. That is a "sand flea," *Sarcopsylla penetrans*, whose female burrows beneath the skin, generally under the toe-nail, where the insect deposits her eggs. This flea must be taken out, or fatal results may follow. The great desideratum here is to study the life of this mite, and identify the adult form.

An Aviation Map of the World and Marks for Aviators

Based on the International World Map

WITH the daily advances in the science of aviation and the many demonstrations of its practicability, we are coming closer and closer to the vital problem of finding a suitable method by which a pilot of the air may locate his position and either verify his course or lay out a new one. This problem has been ably dealt with by the French who have planned a system on which Mr. Ch. Lallemand has reported. There follows here an abstract of this article from the appendix of the annual report of the Smithsonian Institution.

In order to attain the required object, and to preserve the necessary clearness, an air map must show only the details required by aviators, both for finding their way and for landing. First, the characteristic geographical features of the earth are to be considered, such as, railroad lines, roads, rivers, forests, groves of trees, large cultivated areas, large towns with their outlines and principal streets, high chimneys and towers, and all objects liable to attract the attention of the pilot from a distance. Second, the less noticeable but dangerous points are to be reproduced, such as pits, hedges, canals, electric power lines, and other objects liable to impede a landing; besides gasometers, aerodromes and sheds where refuge and assistance may be had.

At Mr. Lallemand's suggestion it was decided that the new map should be a subdivision of the recently adopted "International Map of the World," on a scale of 1 to 1,000,000. The world map to furnish an index diagram for the fitting together of the streets of the air map.

The world map is designed with the meter as the unit of length, and the meridian of Greenwich as the origin of the longitudes. The sheets are limited by meridians drawn out at successive intervals of 6 degrees, extending from Greenwich, and by parallels traced out at successive intervals of 4 degrees, reckoning from the equator.

The meridian sectors, from longitude 180 degrees east or west of Greenwich, are given numbers from 1 to 60, increasing in an easterly direction. The zones, extending from the equator, to 88 degrees latitude, are given letters, from A to V, preceded by the words north or south. The polar areas are lettered Z. Each sheet bears the name of the locality or most important geographical feature of the territory represented, and the number of the sector and the letter of the zone crossing each other on the sheet in question. For example, the sheet on which Paris is located is marked "North M. 31."

For each sheet, the corresponding part of the earth is represented by a modified polyconic projection constructed on its central meridian. The meridians are straight lines, and the parallels, arcs of circles, the centers of which lie on the prolongation of the central meridian.

On the other hand, the sheets of the air map will be limited by meridians and parallels at successive intervals of 1 degree of longitude and 1 degree of latitude, reckoned from the same origins as for the world map. Twenty-four sheets of this map will cover the same area as the corresponding sheet of the world map on the scale of 1 to 1,000,000. As this scale is five times as large, each of these sheets will have approximately the same dimensions as the corresponding sheet of the 1 to 1,000,000 map.

It is customary to distinguish between longitudes east and west of the initial meridian, and between latitudes north and south of the equator. The nomenclature of the latitude and the longitude therefore changes as one passes across either of these lines of origin. In other words, degrees of longitude increase to the right or left from the initial meridian, and degrees of latitude increase both north and south from the equator.

In order to overcome the disadvantage caused by this method it has been decided to number the longitudes from 0 degree to 360 degrees, in an easterly direction commencing from longitude 180 degrees east or west of Greenwich, and to substitute, for latitudes, polar

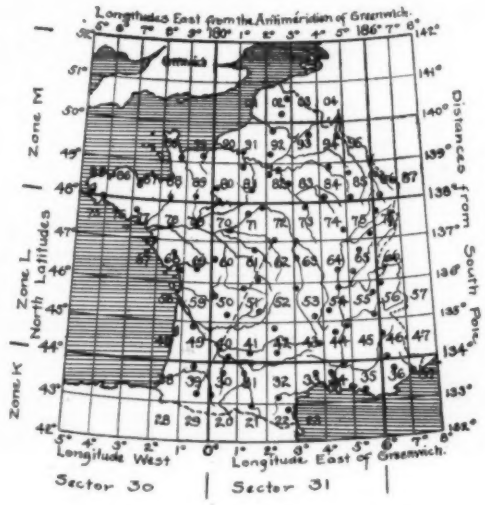


Fig. 1.—Index diagram showing the sheet lines of the Air Map for France.

——— Limits of the sheets of the Air Map. ——— Limits of the sheets of the World Map. 39....72 Numbers of the sheets PAU ... BOURGES, etc. 30, 31, 32 Numbers of the sectors of the World Map. K, L, M Letters of Zones of the World Map. ● Chief towns of departments. ..... Itinerary from Bourges to Pau.

distances measured from the South Pole, and reading from 0 degree to 180 degrees. This is done in order that in the northern hemisphere, where most of the inhabited countries are situated, the numbers may increase as usual from the equator northward. Moreover, in the northern hemisphere, the units of degrees would be the same for a south polar distance as for the corresponding latitude. The units of the longitude adopted will be the same, between 180 degrees and 360 degrees,

Fig. 2.—Aeronautical mark.

Erected on the roof of a building in the environs of Pau, which occupies, in the lower half of sheet 39, the relative position represented by the large dot, both on the above frame and on the index diagram (Fig. 1). The co-ordinates of the SW. corner of the sheet 39 are: 133 degrees south polar distance and 179 degrees new longitude E. reckoned from meridian 180 degrees E. or W. of Greenwich (that is, 43 degrees latitude N. and 1 degree longitude W. of Greenwich).

as they are now for longitudes east of Greenwich. The degrees, in the case of south polar distances, will be increased by 90 units, and, in the case of longitudes east of Greenwich, by 180 units.

Each sheet of the air map will bear the name of the most important locality on the area covered by it, and be numbered by the co-ordinates of its southwestern corner. This number shows the number of degrees of longitude and south polar distance in the co-ordinates of any point in the sheet, and in order to obtain the complete co-ordinates of any given point, it will be sufficient to add to these figures the tenths of degrees or minutes, obtained from the marginal scales.

The "air map" will be constructed on the same modified polyconic projection as that used for the world map. Each sheet being 56 centimeters, or 22 inches high, and from 41 to 34 centimeters broad.

In this system, the distortion of the air map would be 36 times smaller than that of the world map, since a sheet of the air map covers only one degree of longitude, instead of 6 degrees. As the scale of the air map is 5 times as large, the errors from this source are reduced to one seventh of those in the world map.

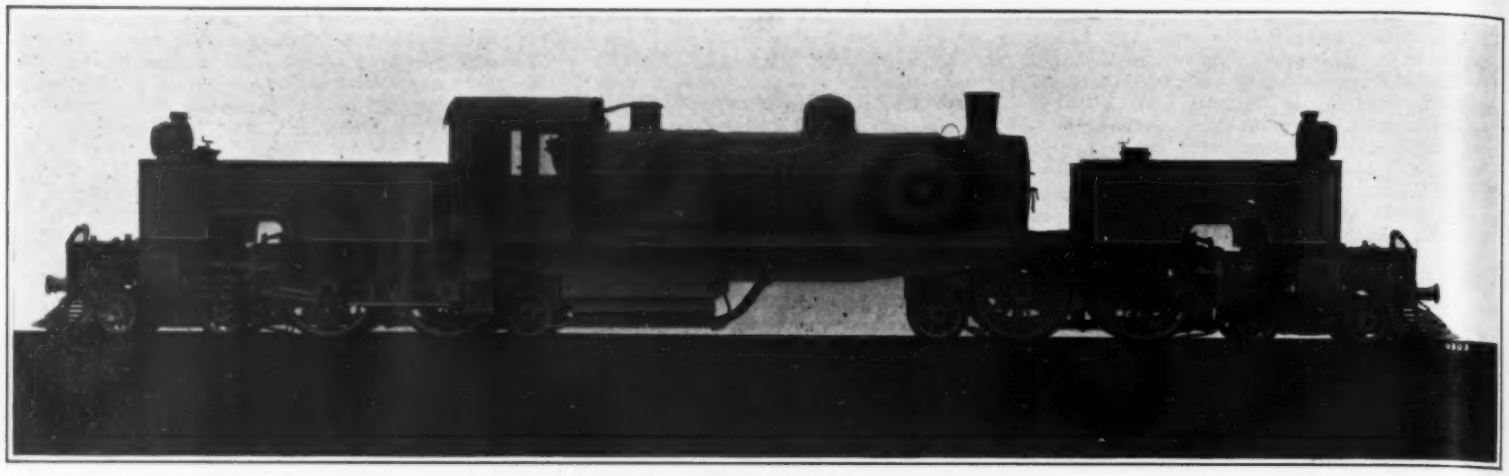
The index map may be used for ascertaining distance to be traversed, and could be used for traveling. A straight line having been laid out between two points, Bourges (dot in 72, Fig. 1) and Pau (dot in 39, Fig. 1), for example, the pilot can see the general line of his route and the sections of the map it crosses. If the pilot saw on the ground beneath him a mark like Fig. 2, but with the figures 5 and 0 on either side and the black dot in the position of the town of Angoulême as it appeared on sheet 50 of the index map (Fig. 1), he would at once conclude that he had deviated from his course to the right, and after an estimation would incline 25 or 30 degrees to the left. Although this map might serve for a trip, a detailed map would be necessary for landing.

As has been mentioned, each mark on the ground should show the approximate longitude and polar distance of its position. The sign adopted by the French Committee consists of a half rectangle (Fig. 2) representing the half sheet of the air map in which the mark lies. Within the frame the black dot indicates the position on the sheet of the mark on the ground. Reading from the south, two large figures are marked on either side of the rectangle, the left one indicating the last digit in the degrees of polar distance, and the right one the last digit in the degrees of the longitude. (See Fig. 2.)

The combination of these two figures, forming a number easy to read and remember, will be sufficient to define the number of the corresponding sheet of the map, and to give the rough co-ordinates of the mark itself.

Owing to the absence of the digits showing the hundreds and tens of degrees of longitude and polar distance, any two marks, which are 10 degrees, or a multiple of 10 degrees apart, will have the same number. This advantage will not be of great importance, however, for an aviator, to confuse two such marks, would mean that he would make an error of 10 degrees of either longitude or latitude. In latitudes between 40 degrees and 50 degrees, this error would amount to 1,100 kilometers (683.5 miles) of latitude, or from 700-800 kilometers (435-497 miles) of longitude, a very great distance.

The initiative taken by France in producing an air map and establishing aeronautical marks will very probably be adopted by the other countries, but in such a case an international agreement would be necessary to make the system conventional. This plan was augmented in May, 1911, by the Cartographical Committee of the International Aeronautical Federation, which met in Brussels and adopted in principle the system offered by the French.



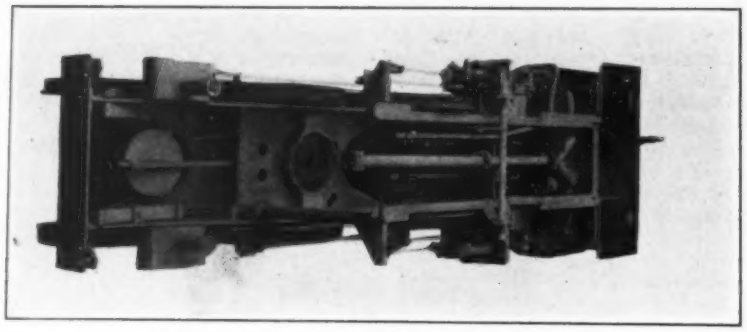
A new type of eight-cylinder locomotive.

Powerful Articulated Narrow Gage Locomotives for Tasmania

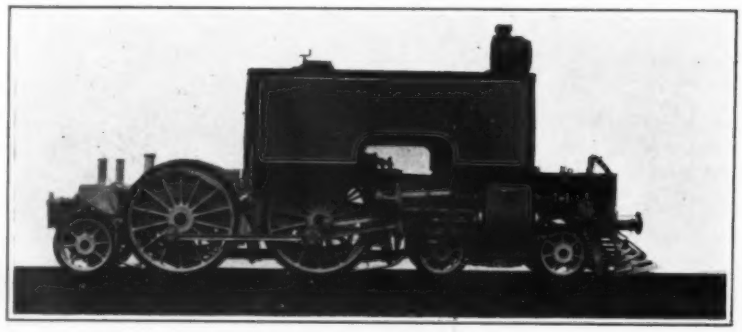
Some months ago we described in the pages of the Scientific American Supplement the interesting "Garratt" locomotive, which had been constructed for the 2-foot gage sections of the Tasmanian government railways. The experience with this locomotive convinced the builders, Beyer, Peacock & Company, Limited, of its possibilities and efficiency so completely that they acquired the patents for the purpose of further developing the idea. Similar locomotives were built for the Darjeeling Mountain railways in the Himalaya for the negotiation of the sharp curves on this line, and to which the locomotive is well adapted. Recently, two new types of this locomotive have been constructed at the Gorton foundry for the freight and passenger service respectively of the Tasmanian railways, the interesting features of which we are permitted to describe through the courtesy of the builders. The new engines herewith illustrated are designed for operation upon the main line gage of 3½ feet, and are called upon to fulfil very stringent requirements.

The essential principles of the "Garratt" type having been described fully in the Supplement, we only propose to point out the leading features of the latest development of this invention, while the accompanying photographs convey a general idea of their appearance. The designs of these engines were laid down by Mr. W. R. Deeble, C.E., the chief mechanical engineer of the railway, to conform to a variety of difficult and rigid requirements for which the "Garratt" locomotive has been found to offer the only solution, and to this engineer is due a considerable amount of the credit for the development of the engine. So far as the passenger locomotive is concerned it is probably the most powerful articulated passenger locomotive that has been built yet for service upon a railway of 3½ feet gage. The restrictions concerning axle load and fixed wheel-base were such as to preclude an ordinary type of locomotive. The high speed demanded also imposed special conditions as to the size and distribution of the wheels and balancing of reciprocating forces, so as to prevent side movement. The ultimate decision therefore was for a Garratt simple passenger locomotive having two groups of four coupled wheels, four-cylinder balanced engines, each having an inner pair of carrying wheels, and an outer four-wheeled bogie: otherwise an Atlantic type of engine, the coupled wheels being 5 feet in diameter with a maximum rigid wheel-base of 6 feet; weight upon driving axles, 11½ to 12 tons; Schmidt's system of superheating; and designed for 50 miles per hour on tangents and 30 miles per hour round reverse curves of 330 yards radius.

The particulars of the passenger engine are as follows:



Plan view of one four-cylinder engine unit.



The front engine unit.

Cylinders	4 inside, 4 outside
Diameter	12 inches
Stroke	20 inches
Driving wheels	5 foot diameter
Heating surface, total	2,019 square feet
Wheel-base, total	20 feet 9 inches
Articulating center apart	30 feet 6 inches
Weight, front engine, full	104,944 pounds
Weight, hind engine, full	106,848 pounds
Total weight of engines on rails	211,792 pounds

The design of freight locomotives was governed by the same factors as were manifest in connection with the design of the passenger engine, except in regard to high speed and axle load, the latter being restricted to 9½ tons. It has two groups of six coupled wheels, two-cylinder engines each having an inner pair of carrying wheels, and an outer two-wheeled radial bogie. The freight engine has an extreme wheel-base of 56 feet 8 inches, while the total weight is 201,572 pounds in running order.

This design gave an increase of tractive force of over 60 per cent more than that possessed by their largest ordinary type of freight locomotive. The boilers for these two types were made duplicates of one another, while all other parts so far as possible were made interchangeable. The absence of side tanks and of wheels below the boiler, both characteristic advantages of the Garratt system, have enabled the provision of a large boiler of a simple and well proportioned design, with a wide and deep fire box of the Belpaire pattern, coupled with a reasonable length of boiler barrel.

The driving, coupled, and inner carrying wheels of the passenger locomotive are compensated together, while the bogie is of the compensated type with swing links. The carrying wheel axle-boxes have a total side play of ¾ inch, controlled by Cartazzi inclined sliding tops. The inside and outside cylinders drive on the same axle, the cranks being placed at an angle of 180 degrees. The special piston valves and packings are of the Schmidt patent type, while the valve gear is outside and of the Walschaert pattern, each valve gear actuating an outside piston valve, and, by means of a rocking shaft, an inside valve. Screw reversing gear is provided controlling simultaneously the valve gear of both engine units. The live steam ball joints are placed directly over the pivot centers, are readily accessible, and easily removable from the top of the engine platform.

In freight locomotives the outer end truck, and first coupled wheel springs are compensated together in one unit, and the intermediate driving and carrying wheels in another. The carrying wheels have plain axle boxes with side play, the longer rigid wheel-base—8 feet in this instance, as compared with the shorter rigid wheel-base of 6 feet in the passenger locomotive—and the slower maximum speed of 20 miles per hour when negotiating the same reverse curves of 330 yards radius, rendering side control of the inner axle-boxes unnecessary.

The trials were carried out under conditions as closely allied to those in actual service as possible, and fully demonstrated the flexibility and steadiness of both classes of locomotives at high speeds. This latest development of the Garratt locomotive has offered conclusive testimony to the fact that the design offers many possibilities for efficient and economical working under difficult conditions upon narrow gage railways, and its application to the standard gage cannot but be a matter of a short while.

Hardening Soft Iron

To harden soft iron, wet it with water, and scatter over its surface powdered yellow prussiate of potash; then heat to a cherry-red heat, which causes the potash to melt and coat the surface of the soft iron; then immerse quickly in cold water, and repeat the operation. A white heat must not be used, as this would not harden, but oxidize, the iron. Care must be used not to use red prussiate of potash instead of the yellow; it will not answer.—*English Mechanic and World of Science.*

Power from Waste Heat

Consul Walter C. Hamm, Newcastle, England, states that West Hartlepool, which can claim to be the first municipal authority to produce electricity by means of waste heat, will open its new generating station in the course of two or three weeks. The two turbo-generators, each of 1,500 kilowatts, will be driven by exhaust steam from the furnace-blowing engines of the Seaton Carew Iron Company, adjacent to whose works the station is built. In return for their exhaust steam, which has hitherto been blowing to waste in the air, the Seaton Carew Iron Company will receive free from the corporation the supply of electric current they need at their works.

Expenditure on coal will practically be eliminated. The coal bill for the present electricity station is about $20,000 a year, and, as it is anticipated that the consumption of current will largely increase under the cheaper rate now possible, the ultimate saving by the use of waste heat will be very considerable. Should the supply of exhaust steam not be available, either through a breakdown of the blowing engines or through the iron works being idle, a supply of high-pressure steam will be obtainable from the Seaton Carew Iron Company.

The total expenditure involved in connection with the new scheme is $188,500, the plant alone having cost $150,000. The old generating station will be maintained as a stand-by, and also as a town sub-station. There the current from the new station will be transferred to the voltage which will be required for distribution to the town.—*Journal of Industrial and Engineering Chemistry.*

Continuity—I

The Atomistic Trend of Modern Research, and a Plea for Conservatism

Presidential Address Before the British Association

By Sir Oliver Lodge

"Natura non vincitur nisi parendo."

ELIMINATING from our purview, as is always necessary, a great mass of human activity, and limiting ourselves to a scrutiny on the side of pure science alone, let us ask what, in the main, is the characteristic of the promising though perturbing period in which we live. Different persons would give different answers, but the answer I venture to give is: Rapid progress, combined with Fundamental skepticism.

Rapid progress was not characteristic of the latter half of the nineteenth century, at least not in physics. Fine solid dynamical foundations were laid, and the edifice of knowledge was consolidated; but wholly fresh ground was not being opened up, and totally new buildings were not expected.

"In many cases the student was led to believe that the main facts of nature were all known, that the chances of any great discovery being made by experiment were vanishingly small, and that therefore the experimentalist's work consisted in deciding between rival theories, or in finding some small residual effect, which might add a more or less important detail to the theory."—*Schuster.*

With the realization of predicted ether waves in 1888, the discovery of X-rays in 1895, spontaneous radioactivity in 1896, and the isolation of the electron in 1898, expectation of further achievement became vivid; and novelties, experimental theoretical and speculative, have been showered upon us ever since this century began. That is why I speak of rapid progress.

Of the progress I shall say little, there must always be some uncertainty as to which particular achievement permanently contributes to it; but I will speak about the fundamental skepticism.

Let me hasten to explain that I do not mean the well-worn and almost antique theme of Theological skepticism; that controversy is practically in abeyance just now. At any rate the major conflict is suspended; the forts behind which the enemy has retreated do not invite attack; the territory now occupied by him is little more than his legitimate province. It is the scientific allies, now, who are waging a more or less invigorating conflict among themselves; with Philosophers joining in. Meanwhile the ancient foe is biding his time and hoping that from the struggle something will emerge of benefit to himself. Some positions, he feels, were too hastily abandoned and may perhaps be retrieved; or, to put it without metaphor, it seems possible that a few of the things prematurely denied, because asserted on inconclusive evidence, may after all, in some form or other, have really happened. Thus the old theological bitterness is mitigated, and a temporising policy is either advocated or instinctively adopted.

To illustrate the nature of the fundamental scientific or philosophic controversies to which I do refer, would require almost as many addresses as there are Sections of the British Association, or at any rate as many as there are chief cities in Australia; and perhaps my successor in the Chair will continue the theme; but, to exhibit my meaning very briefly, I may cite the kind of dominating controversies now extant, employing as far as possible only a single word in each case so as to emphasize the necessary brevity and insufficiency of the reference.

In Physiology the conflict ranges round *Vitalism.* (My immediate predecessor dealt with the subject at Dundee.)

In Chemistry the debate concerns *Atomic structure.* (My penultimate predecessor is well aware of pugnacity in that region.)

In Biology the dispute is on the laws of *Inheritance.* (My successor is sure to deal with this subject; probably in a way not deficient in liveliness.)

And besides these major controversies, debate is active in other sections:

In Education, *Curricula* generally are being overhauled or fundamentally criticized, and revolutionary ideas are promulgated concerning the advantages of freedom for infants.

In Economic and Political Science, or Sociology, what is there that is not under discussion? Not property alone, nor land alone, but everything, back to the garden of Eden and the inter-relations of men and women.

Lastly, in the vast group of Mathematical and Physical Sciences, "slurred over rather than summed up as Section A," present-day skepticism concerns what, if I had to express it in one word, I should call *Continuity.* The full meaning of this term will hardly be intelligible without explanation, and I shall discuss it presently.

Still more fundamental and deep-rooted than any of these sectional debates, however, a critical examination of scientific foundations generally is going on; and a kind of philosophic skepticism is in the ascendant, resulting in a mistrust of purely intellectual processes and in a recognition of the limited scope of science.

For science is undoubtedly an affair of the intellect, it examines everything in the cold light of reason; and that is its strength. It is a commonplace to say that science must have no likes or dislikes, must aim only at truth; or as Bertrand Russell well puts it:

"The kernel of the scientific outlook is the refusal to regard our own desires, tastes, and interests as affording a key to the understanding of the world."

This exclusive single-eyed attitude of science is its strength; but, if pressed beyond the positive region of usefulness into a field of dogmatic negation and philosophizing, it becomes also its weakness. For the nature of man is a large thing, and intellect is only a part of it; a recent part, too, which therefore necessarily, though not consciously, suffers from some of the defects of newness and crudity, and should refrain from imagining itself the whole, perhaps it is not even the best part, of human nature.

The fact is that some of the best things are, by abstraction, excluded from Science, though not from Literature and Poetry; hence, perhaps an ancient mistrust or dislike of science, typefied by the Promethean legend. Science is systematized and *metrical* knowledge, and in regions where measurement cannot be applied it has small scope; or, as Mr. Balfour said the other day at the opening of a new wing of the National Physical Laboratory:

"Science depends on measurement, and things not measurable are therefore excluded, or tend to be excluded, from its attention. But Life and Beauty and Happiness are not measurable." And then characteristically he adds: "If there could be a unit of happiness, Politics might begin to be scientific."

Emotion and Intuition and Instinct are immensely older than science, and in a comprehensive survey of existence they cannot be ignored. Scientific men may rightly neglect them, in order to do their proper work, but philosophers cannot.

So Philosophers have begun to question some of the larger generalizations of science, and to ask whether in the effort to be universal and comprehensive we have not extended our laboratory inductions too far. The Conservation of Energy, for instance, is it always and everywhere valid; or may it under some conditions be disobeyed? It would seem as if the second law of Thermodynamics must be somewhere disobeyed, at least if the age of the Universe is both ways infinite, else the final consummation would have already arrived.

Not by philosophers only, but by scientific men also, ancient postulates are being pulled up by the roots. Physicists and Mathematicians are beginning to consider whether the long known and well-established laws of mechanics hold true everywhere and always, or whether the Newtonian scheme must be replaced by something more modern, something to which Newton's laws of motion are but an approximation.

Indeed, a whole system of non-Newtonian Mechanics has been devised, having as its foundation the recently discovered changes which must occur in bodies moving at speeds nearly comparable with that of light. It turns out in fact that both Shape and Mass are functions of Velocity. As the speed increases the mass increases and the shape is distorted, though under ordinary conditions only to an infinitesimal extent.

So far I agree; I agree with the statement of fact; but I do not consider it so revolutionary as to overturn Newtonian mechanics. After all, a variation of Mass is familiar enough, and it would be a great mistake to say that Newton's second law breaks down merely because Mass is not constant. A raindrop is an example of variable mass; or the earth may be, by reason of meteoric dust; or the sun, by reason of radio-activity; or a locomotive, by reason of the emission of steam. In fact, variable masses are the commonest, for friction may abrade any moving body to a microscopic extent.

That Mass is constant is only an approximation. That Mass is equal to ratio of Force and Acceleration is a definition, and can be absolutely accurate. It holds perfectly even for an electron with a speed near that of light; and it is by means of Newton's second law that the variation of Mass with Velocity has been experimentally observed and compared with theory.

I urge that we remain with, or go back to, Newton. I see no reason against retaining all Newton's laws, discarding nothing, but supplementing them in the light of further knowledge.

Even the laws of Geometry have been overhauled, and Euclidean Geometry is seen to be but a special case of more fundamental generalizations. How far they apply to existing space, and how far Time is a reality or an illusion, and whether it can in any sense depend on the motion or the position of an observer; all these things in some form or other are discussed.

The Conservation of Matter also, that main-mast of nineteenth century chemistry, and the existence of the Ether of Space, that sheet-anchor of nineteenth century physics, do they not sometimes seem to be going by the board?

Prof. Schuster, in his American lectures, commented on the modern receptive attitude as follows:

"The state of plasticity and flux, a healthy state, in my opinion, in which scientific thought of the present day adapts itself to almost any novelty, is illustrated by the complacency with which the most cherished tenets of our fathers are being abandoned. Though it was never an article of orthodox faith that chemical elements were immutable and would not some day be resolved into simpler constituents, yet the conservation of mass seemed to lie at the very foundation of creation. But now-a-days the student finds little to disturb him, perhaps too little, in the idea that mass changes with velocity; and he does not always realize the full meaning of the consequences which are involved."

This readiness to accept and incorporate new facts into the scheme of physics may have led to perhaps an undue amount of scientific skepticism, in order to right the balance.

But a still deeper variety of comprehensive skepticism exists, and it is argued that all our laws of nature, so laboriously ascertained and carefully formulated, are but conventions after all, not truths; that we have no faculty for ascertaining real truth, that our intelligence was not evolved for any such academic purpose; that all we can do is to express things in a form convenient for present purposes and employ that mode of expression as a tentative and pragmatically useful explanation.

Even *explanation*, however, has been discarded as too ambitious by some men of science, who claim only the power to describe. They not only emphasize the *how* rather than the *why*, as is in some sort inevitable, since explanations are never ultimate, but are satisfied with very abstract propositions, and regard mathematical equations as preferable to, because safer than, mechanical analogies or models.

"To use an acute and familiar expression of Gustav Kirchhoff, it is the object of science to *describe* natural phenomena, not to *explain* them. When we have expressed by an equation the correct relationship between different natural phenomena we have gone as far as we safely can, and if we go beyond we are entering on purely speculative ground."

But the modes of statement preferred by those who distrust our power of going correctly into detail are far from satisfactory. Prof. Schuster describes and comments on them thus:

"Vagueness, which used to be recognized as our great enemy, is now being enshrined as an idol to be worshipped. We may never know what constitutes atoms, or what is the real structure of the ether; why trouble, therefore, it is said, to find out more about them. Is it not safer, on the contrary, to confine ourselves to a general talk on entropy, luminiferous vectors, and undefined symbols expressing vaguely certain physical relationships? What really lies at the bottom of the great fascination which these new doctrines exert on the present generation is sheer cowardice; the fear of having its errors brought home to it." . . .

"I believe this doctrine to be fatal to a healthy development of science. Granting the impossibility of penetrating beyond the most superficial layers of observed phenomena, I would put the distinction between the two attitudes of mind in this way: One glorifies our ignorance, while the other accepts it as a regrettable necessity."

In further illustration of the modern skeptical attitude, I quote from Poincaré:

"Principles are conventions and definitions in disguise. They are, however, deduced from experimental laws, and these laws have, so to speak, been erected into principles to which our mind attributes an absolute value." . . .

"The fundamental propositions of geometry, for instance Euclid's postulate, are only conventions; and it is quite as unreasonable to ask if they are true or false as to ask if the metric system is true or false. Only, these conventions are convenient." . . .

"Whether the ether exists or not matters little, let us leave that to the metaphysicians; what is essential for us is that everything happens as if it existed, and that this hypothesis is found to be suitable for the explanation of phenomena. After all, have we any other reason for believing in the existence of material objects? That, too, is only a convenient hypothesis."

As an antidote against over-pressing these utterances I quote from Sir J. Larmor's Preface:

"There has been of late a growing trend of opinion, prompted in part by general philosophical views, in the direction that the theoretical constructions of physical science are largely factitious, that instead of presenting a valid image of the relations of things on which further progress can be based, they are still little better than a mirage." . . .

"The best method of abating this skepticism is to become acquainted with the real scope and modes of application of conceptions which, in the popular language of superficial exposition, and even in the unguarded and playful paradox of their authors, intended only for the instructed eye, often look bizarre enough."

One thing is very notable, that it is closer and more exact knowledge that has led to the kind of scientific skepticism now referred to; and that the simple laws on which we used to be working were thus simple and discoverable because the full complexity of existence was tempered to our ken by the roughness of our means of observation.

Kepler's laws are not accurately true, and if he had had before him all the data now available he could hardly have discovered them. A planet does not really move in an ellipse but in a kind of hypocycloid, and not accurately in that either.

So it is also with Boyle's law, and the other simple laws in Physical Chemistry. Even Van der Waals' generalization of Boyle's law is only a further approximation.

In most parts of physics simplicity has sooner or later to give place to complexity; though certainly I urge that the simple laws were true, and are still true, as far as they go, their inaccuracy being only detected by further real discovery. The reason they are departed from becomes known to us; the law is not really disobeyed, but is modified through the action of a known additional cause. Hence, it is all in the direction of progress.

It is only fair to quote Poincaré again, now that I am able in the main to agree with him:

"Take, for instance, the laws of reflection. Fresnel established them by a simple and attractive theory which experiment seemed to confirm. Subsequently, more accurate researches have shown that this verification was but approximate; traces of elliptic polarization were detected everywhere. But it is owing to the first approximation that the cause of these anomalies was found, in the existence of a transition layer; and all the essentials of Fresnel's theory have remained. We cannot help reflecting that all these relations would never have been noted if there had been doubt in the first place as to the complexity of the objects they connect. Long ago it was said: If Tycho had had instruments ten times as precise, we would never have had a Kepler, or a Newton, or Astronomy. It is a misfortune for a science to be born too late, when the means of observation have become too perfect. That is what is happening at this moment with respect to physical chemistry; the founders are hampered in their general grasp by third and fourth decimal places; happily they are men of robust faith. As we get to know the properties of matter better we see that continuity reigns. . . . . It would be difficult to justify [the belief in continuity] by apodeictic reasoning, but without [it] all science would be impossible."

Here he touches on my own theme, *Continuity;* for, if we had to summarize the main trend of physical controversy at present, I feel inclined to urge that it largely turns on the question as to which way ultimate victory lies in the fight between Continuity and Discontinuity.

On the surface of nature at first we see discontinuity; objects detached and countable. Then we realize the air and other media, and so emphasize continuity and flowing quantities. Then we detect atoms and numerical properties, and discontinuity once more makes its appearance. Then we invent the ether and are impressed with continuity again. But this is not likely to be the end: and what the ultimate end will be, or whether there is an ultimate end, is a question difficult to answer.

The modern tendency is to emphasize the discontinuous or atomic character of everything. Matter has long been atomic, in the same sense as Anthropology is atomic; the unit of matter is the atom, as the unit of humanity is the individual. Whether men or women or children, they can be counted as so many "souls." And atoms of matter can be counted too.

Certainly, however, there is an illusion of continuity. We recognize it in the case of water. It appears to be a continuous medium, and yet it is certainly molecular. It is made continuous again, in a sense, by the ether postulated in its pores; for the ether is essentially continuous. Though Osborne Reynolds, it is true, invented a discontinuous or granular Ether, on the analogy of the sea shore. The sands of the sea, the hairs of the head, the descendants of a Patriarch, are typical instances of numerable, or rather of innumerable, things. The difficulty of enumerating them is not that there is nothing to count, but merely that the things to be counted are very numerous. So are the atoms in a drop of water, they outnumber the drops in an Atlantic Ocean, and, during the briefest time of stating their number, fifty millions or so may have evaporated; but they are as easy to count as the grains of sand on a shore.

The process of counting is evidently a process applicable to discontinuities, i. e., to things with natural units; you can count apples and coins, and days and years, and people and atoms. To apply number to a continuum you must first cut it up into artificial units; and you are always left with incommensurable fractions. Thus, only is it that you can deal numerically with such continuous phenomena as the warmth of a room, the speed of a bird, the pull of a rope, or the strength of a current.

But how, it may be asked, does discontinuity apply to number? The natural numbers, 1, 2, 3, etc., are discontinuous enough, but there are fractions to fill up the interstices; how do we know that they are not really connected by these fractions, and so made continuous again?

(By number I always mean commensurable number; incommensurables are not numbers; they are just what cannot be expressed in numbers. The square root of 2 is not a number, though it can be readily indicated by a length. Incommensurables are usual in physics and are frequent in geometry; the conceptions of geometry are essentially continuous. It is clear, as Poincaré says, that "if the points whose co-ordinates are commensurable were alone regarded as real, the in-circle of a square and the diagonal of the square would not intersect, since the co-ordinates of the points of intersection are incommensurable.")

I want to explain how commensurable fractions do not connect up numbers, nor remove their discontinuity in the least. The divisions on a foot rule, divided as closely as you please, represent commensurable fractions, but they represent none of the length. No matter how numerous they are, all the length lies between them; the divisions are mere partitions and have consumed none of it; nor do they connect up with each other, they are essentially discontinuous. The interspaces are infinitely more extensive than the barriers which partition them off from one another; they are like a row of compartments with infinitely thin walls. All the incommensurables lie in the interspaces; the compartments are full of them, and they are thus infinitely more numerous than the numerically expressible magnitudes. Take any point of the scale at random, that point will certainly lie in an interspace; it will not lie on a division, for the chances are infinity to 1 against it.

Accordingly incommensurable quantities are the rule in physics. Decimals do not in practice terminate or circulate, in other words vulgar fractions do not accidentally occur in any measurements, for this would mean infinite accuracy. We proceed to as many places of decimals as correspond to the order of accuracy aimed at.

Whenever, then, a commensurable number is really associated with any natural phenomenon, there is necessarily a noteworthy circumstance involved in the fact, and it means something quite definite and ultimately ascertainable. Every discontinuity that can be detected and counted is an addition to knowledge. It not only means the discovery of natural units instead of being dependent on artificial ones, but it throws light also on the nature of phenomena themselves.

For instance:

The ratio between the velocity of light and the inverted square root of the product of the electric and magnetic constants was discovered by Clerk Maxwell to be 1; and a new volume of physics was by that discovery opened.

Dalton found that chemical combination occurred between quantities of different substances specified by certain whole or fractional numbers; and the atomic theory of matter sprang into substantial though at first infantile existence.

The hypothesis of Prout, which in some modified form seems likely to be substantiated, is that all atomic weights are commensurable numbers; in which case there must be a natural fundamental unit underlying and in definite groups composing, the atoms of every form of matter.

The small number of degrees of freedom of a molecule, and the subdivision of its total energy into equal parts corresponding thereto, is a theme not indeed without difficulty but full of importance. It is responsible for the suggestion that energy too may be atomic!

Mendelejeff's series again, or the detection of a natural grouping of atomic weights in families of seven, is another example of the significance of number.

Electricity was found by Faraday to be numerically connected with quantity of matter; and the atom of electricity began its hesitating but now brilliant career.

Electricity itself, i. e., electric charge, strangely enough has proved itself to be atomic. There is a natural unit of electric charge, as suspected by Faraday and Maxwell and named by Johnstone Stoney. Some of the electron's visible effects were studied by Crookes in a vacuum; and its weighting and measuring by J. J. Thomson were announced to the British Association meeting at Dover in 1899, a fitting prelude to the twentieth century.

An electron is the natural unit of negative electricity, and it may not be long before the natural unit of positive electricity is found too. But concerning the nature of the positive unit there is at present some division into opposite camps. One school prefers to regard the unit of positive electricity as a homogeneous sphere, the size of an atom, in which electrons revolve in simple harmonic orbits and constitute nearly the whole effective mass. Another school, while appreciative of the simplicity and ingenuity and beauty of the details of this conception, and the skill with which it has been worked out, yet thinks the evidence more in favor of a minute central positive nucleus, or nucleus-group, of practically atomic mass; with electrons, larger—i.e. less concentrated,—and therefore less massive than itself, revolving round it in astronomical orbits. While from yet another point of view it is insisted that positive and negative electrons can only differ skew-symmetrically, one being like the image of the other in a mirror, and that the mode in which thay are grouped to form an atom remains for future discovery. But no one doubts that electricity is ultimately atomic.

We may express all this as an invasion of number into unsuspected regions.

Biology may be said to be becoming atomic. It has long had natural units in the shape of cells and nuclei, and some discontinuity represented by body boundaries and cell-walls; but now, in its laws of heredity as studied by Mendel, number and discontinuity are strikingly apparent among the reproductive cells, and the varieties of offspring admit of numerical specifications and prediction to a surprising extent: while modification by continuous variation, which seemed to be of the essence of Darwinism, gives place to, or at least is accompanied by, mutation, with finite and considerable and in appearance discontinuous change.

So far from nature not making jumps, it becomes doubtful if she does anything else. Her hitherto placid course, more closely examined, seems to look like a kind of steeplechase.

Yet undoubtedly Continuity is the backbone of evolution, as taught by all biologists, no artificial boundaries or demarcations between species, a continuous chain of heredity from far below the amœba up to man. Actual continuity of undying germ-plasm, running through all generations, is taught likewise.

Discontinuity does not fail to exercise facination even in pure Mathematics. Curves are invented which have no tangent or differential coefficient, curves which consist of a succession of dots or of twists; and the theory of commensurable numbers seems to be exerting a dominance over philosophic mathematical thought as well as over physical problems.

And not only these fairly accepted results are prominent, but some more difficult and unexpected theses in the same direction are being propounded, and the atomic character of Energy is advocated. We had hoped to be honored by the presence of Professor Planck, whose theory of the *quantum*, or indivisible unit or atom of energy, excites the greatest interest, and by some is thought to hold the field.

Then again Radiation is showing signs of becoming atomic or discontinuous. The corpuscular theory of radiation is by no means so dead as in my youth we thought it was. Some radiation is certainly corpuscular, and even the etherial kind shows indications, which may be misleading, that it is spotty, or locally concentrated into points, as if the wavefront consisted of detached specks or patches; or, as J. J. Thomson says, "the wavefront must be more analogous to bright specks on a dark ground than to a uniformly illuminated surface," thus suggesting that the Ether may be fibrous in structure, and that a wave runs along lines of electric force; as the

genius of Faraday surmised might be possible, in his "Thoughts on Ray Vibrations." Indeed Newton guessed something of the same kind, I fancy, when he superposed ether-pulses on his corpuscles.

Why is so much importance attached to Radiation? Because it is the best known and longest-studied link between matter and ether, and the only property we are acquainted with that affects the unmodified great mass of ether alone. Electricity and magnetism are associated with the modifications or singularities called electrons: most phenomena are connected still more directly with matter. Radiation, however, though excited by an accelerated electron, is subsequently let loose in the ether of space, and travels as a definite thing at a measurable and constant pace, a pace independent of everything so long as the ether is free, unmodified and unloaded by matter. Hence radiation has much to teach us, and we have much to learn concerning its nature.

How far can the analogy of granular, corpuscular, countable, atomic, or discontinuous things be pressed? There are those who think it can be pressed very far. But to avoid misunderstanding let me state, for what it may be worth, that I myself am an upholder of *ultimate* Continuity, and a fervent believer in the Ether of Space.

We have already learnt something about the ether; and although there may be almost as many varieties of opinion as there are people qualified to form one, in my view we have learnt as follows:

The Ether is the universal connecting medium which binds the universe together, and makes it a coherent whole instead of a chaotic collection of independent isolated fragments. It is the vehicle of transmission of all manner of force, from gravitation down to cohesion and chemical affinity; it is therefore the storehouse of potential energy.

Matter moves, but Ether is strained.

What we call elasticity of matter is only the result of an alteration of configuration due to movement and readjustment of particles, but all the strain and stress are in the ether. The ether itself does not move, that is to say it does not move in the sense of locomotion, though it is probably in a violent state of rotational or turbulent motion in its smallest parts; and to that motion its exceeding rigidity is due.

As to its density, it must be far greater than that of any form of matter, millions of times denser than lead or platinum. Yet matter moves through it with perfect freedom, without any friction or viscosity. There is nothing paradoxical in this: viscosity is not a function of density; the two are not necessarily connected. When a solid moves through an alien fluid it is true that it acquires a spurious or apparent extra inertia from the fluid it displaces; but, in the case of matter and ether, not only is even the densest matter excessively porous and discontinuous, with vast interspaces in and among the atoms, but the constitution of matter is such that there appears to be no displacement in the ordinary sense at all; the ether is itself so modified as to *constitute* the matter in some way. Of course that portion moves, its inertia is what we observe, and its amount depends on the potential energy in its associated electric field, but the motion is not like that of a foreign body, it is that of some inherent and merely individualised portion of the stuff itself. Certain it is that the ether exhibits no trace of viscosity.[1]

Matter in motion, Ether under strain, constitute the fundamental concrete things we have to do with in physics. The first pair represent kinetic energy, the second potential energy; and all the activities of the material universe are represented by alternations from one of these forms to the other.

Whenever this transference and transformation of energy occur, work is done, and some effect is produced, but the energy is never diminished in quantity: it is merely passed on from one body to another, always from ether to matter or *vice versa*, except in the case of radiation, which simulates matter, and from one form to another.

The forms of energy can be classified as either a translation, a rotation, or a vibration of pieces of matter of different sizes, from stars and planets down to atoms and electrons; or else an etherial strain which in various different ways is manifested by the behavior of such masses of matter as appeal to our senses.[2]

Some of the facts responsible for the suggestion that energy is atomic seem to me to depend on the discontinuous nature of the structure of a material atom, and on the high velocity of its constituent particles. The apparently discontinuous emission of radiation is, I believe, due to features in the real discontinuity of matter. Disturbances inside an atom appear to be essentially catastrophic; a portion is liable to be ejected with violence. There appears to be a critical velocity below which ejection does not take place; and, when it does, there also occurs a sudden re-arrangement of parts which is presumably responsible for some perceptible etherial radiation. Hence it is, I suppose, that radiation comes off in gushes or bursts; and hence it appears to consist of indivisible units. The occasional phenomenon of new stars, as compared with the steady orbital motion of the millions of recognized bodies, may be suggested as an astronomical analogue.

The Hypothesis of *quanta* was devised to reconcile the law that the energy of a group of colliding molecules must in the long run be equally shared among all their degrees of freedom, with the observed fact that the energy is really shared into only a small number of equal parts. For if vibration-possibilities have to be taken into account, the number of degrees of molecular freedom must be very large, and energy shared among them ought soon to be all frittered away; whereas it is not. Hence the idea is suggested that minor degrees of freedom are initially excluded from sharing the energy, because they cannot be supplied with less than one atom of it.

I should prefer to express the fact by saying that the ordinary encounters of molecules are not of a kind able to excite atomic vibrations, or in any way to disturb the ether. Spectroscopic or luminous vibrations of an atom are excited only by an exceptionally violent kind of collision, which may be spoken of as chemical clash; the ordinary molecular orbital encounters, always going on at the rate of millions a second, are ineffective in that respect, except in the case of phosphorescent or luminescent substances. That common molecular deflexions *are* ineffective is certain, else all the energy would be dissipated or transferred from matter into the ether; and the reasonableness of their radiative inefficiency is not far to seek, when we consider the comparatively leisurely character of molecular movements, at speeds comparable with the velocity of sound. Admittedly, however, the effective rigidity of molecules must be complete, otherwise the sharing of energy must ultimately occur. They do not seem able to be set vibrating by anything less than a certain minimum stimulus; and that is the basis for the theory of *quanta*.

Quantitative applications of Planck's theory, to elucidate the otherwise shaky stability of the astronomically constituted atom, have been made; and the agreement between results so calculated and those observed, including a determination of series of spectrum lines is very remarkable. One of the latest contributions to this subject is a paper by Dr. Bohr in the Philosophical Magazine for July this year.

To show that I am not exaggerating the modern tendency towards discontinuity, I quote, from M Poincaré's *Dérnieres Pensées*, a proposition which he announces in italics as representing a form of Professor Planck's view of which he apparently approves:

"A physical system is susceptible of a finite number only of distinct conditions; it jumps from one of these conditions to another without passing through a continuous series of intermediate conditions."

Also this from Sir Joseph Larmor's Preface to Poincaré's *Science and Hypothesis:*

"Still more recently it has been found that the good Bishop Berkeley's logical jibes against the Newtonian ideas of fluxions and limiting ratios cannot be adequately appeased in the rigorous mathematical conscience, until our apparent continuities are resolved mentally into discrete aggregates which we only partially apprehend. The irresistible impulse to atomize everything thus proves to be not merely a disease of the physicist: a deeper origin, in the nature of knowledge itself, is suggested."

One very valid excuse for this prevalent attitude is the astonishing progress that has been made in actually seeing or almost seeing the molecules, and studying their arrangement and distribution.

The laws of gases have been found to apply to emulsions and to fine powders in suspension, of which the Brownian movement has long been known. This movement is caused by the orthodox molecular bombardment, and its average amplitude exactly represents the theoretical mean free path calculated from the "molecular weight" of the relatively gigantic particles. The behavior of these microscopically visible masses corresponds closely and quantitatively with what could be predicted for them as fearfully heavy atoms, on the kinetic theory of gases; they may indeed be said to constitute a gas with a gram-molecule as high as 200,000 tons; and, what is rather important as well as interesting, they tend visibly to verify the law of equipartition of energy even in so extreme a case, when that law is properly stated and applied.

Still more remarkable, the application of X-rays to display the arrangement of molecules in crystals, and ultimately the arrangement of atoms in molecules, as initiated by Prof. Laue with Drs. Friedrich and Knipping, and continued by Prof. Bragg and his son and by Dr. Tutton, constitute a series of researches of high interest and promise. By this means many of the theoretical anticipations of our countrymen, Mr. William Barlow, and, working with him, Professor Pope, as well as of those distinguished crystallographers von Groth and von Fedorow, have been confirmed in a striking way. These brilliant researches, which seem likely to constitute a branch of Physics in themselves, and which are being continued by Messrs. Moseley and C. G. Darwin, and by Mr. Keene and others, may be called an apotheosis of the atomic theory of matter.

One other controversial topic I shall touch upon in the domain of physics, though I shall touch upon it lightly for it is not a matter for easy reference as yet. If the *Principle of Relativity* in an extreme sense establishes itself, it seems as if even Time would become discontinuous and be supplied in atoms, as money is doled out in pence or centimes instead of continuously; in which case our customary existance will turn out to be no more really continuous than the events on a kinematograph screen, while that great agent of continuity, the Ether of Space, will be relegated to the museum of curiosities.

In that case differential equations will cease to represent the facts of nature. they will have to be replaced by Finite Differences, and the most fundamental revolution since Newton will be inaugurated.

Now in all the debatable matters of which I have indicated possibilities I want to urge a conservative attitude. I accept the new experimental results on which some of these theories, such as the Principle of Relativity, are based, and am profoundly interested in them, but I do not feel that they are as revolutionary as their propounders think. I see a way to retain the old and yet embrace the new, and I urge moderation in the uprooting and removal of landmarks.

And of these the Chief is Continuity. I cannot imagine the exertion of mechanical force across empty space, no matter how minute; a continuous medium seems to me essential. I cannot admit discontinuity in either Space or Time, nor can I imagine any sort of experiment which would justify such a hypothesis. For surely we must realize that we know nothing experimental of either space or time, we cannot modify them in any way. We make experiments on bodies, and only on bodies, using 'body' as an exceedingly general term.

We have no reason to postulate anything but continuity for space and time. We cut them up into conventional units for convenience' sake, and those units we can count; but there is really nothing atomic or countable about the things themselves. We can count the rotations of the earth, or the revolutions of an electron, or the vibrations of a pendulum, or the waves of light. All these are concrete and tractable physical entities; but space and time are ultimate data, abstractions based on experience. We know them through motion, and through motion only, and motion is essentially continuous. We ought clearly to discriminate between things themselves and our mode of measuring them. Our measures and perceptions may be affected by all manner of incidental and trivial causes, and we may get confused or hampered by our own movement; but there need be no such complication in things themselves, any more than a landscape is distorted by looking at it through an irregular window-pane or from a traveling coach. It is an ancient and discarded fable that complications introduced by the motion of an observer are real complications belonging to the outer universe.

Very well, then, what about the Ether, is that in the same predicament? Is that an abstraction, or a mere convention, or is it a concrete physical entity on which we can experiment?

Now it has to be freely admitted that it is exceedingly difficult to make experiments on the ether. It does not appeal to sense, and we know no means of getting hold of it. The one thing we know metrical about it is the velocity with which it can transmit transverse waves. That is clear and definite, and thereby to my judgement it proves itself a physical agent; not indeed tangible or sensible, but yet concretely real.

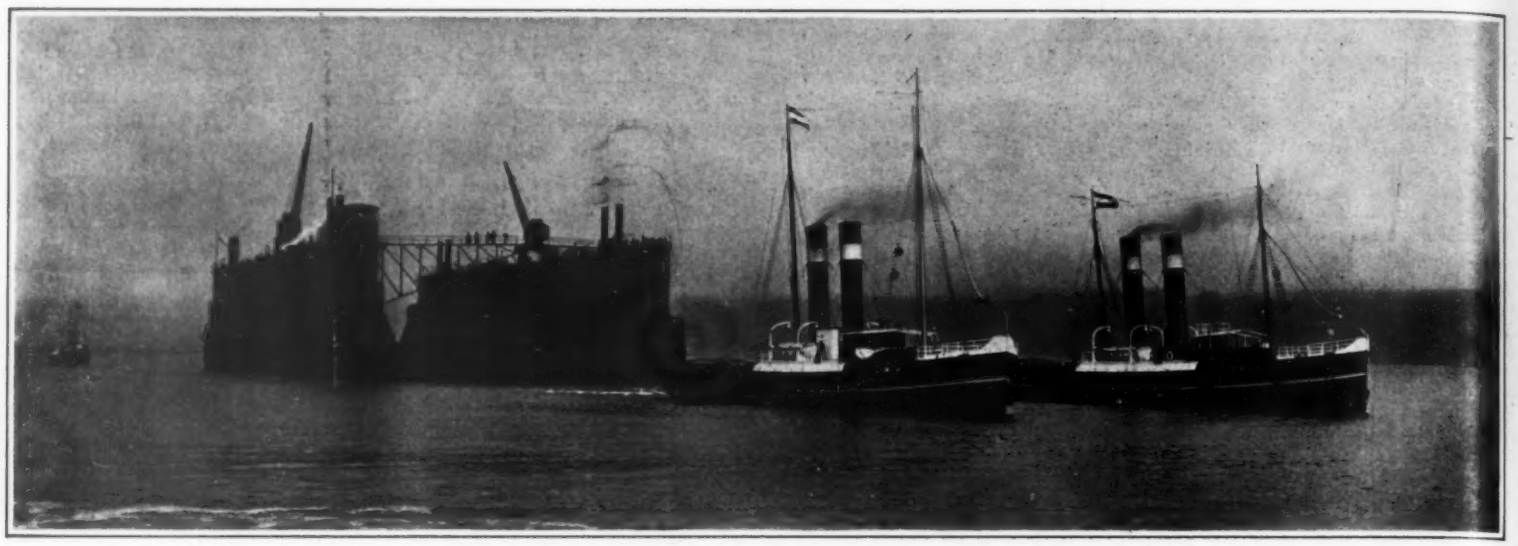
But it does elude our laboratory grasp. If we rapidly move matter through it, hoping to grip it and move it too, we fail; there is no mechanical connection. And even if we experiment on light we fail too. So long as transparent matter is moving relatively to us, light can be affected inside that matter; but when matter is relatively stationary to matter nothing observable takes place, however fast things may be moving, so long as they move together.

Hence, arises the idea that motion with respect to Ether is meaningless; and the fact that only relative motion of pieces of matter with respect to each other has so far been observed is the foundation of the Principle of Relativity. It sounds simple enough as thus stated, but in its developments it is an ingenious and complicated doctrine embodying surprising consequences which have been worked out by Prof. Einstein and his disciples with consummate ingenuity.

[*The portion of Sir Oliver Lodge's presidential address which has attracted most attention in the lay press is the concluding section, in which the speaker expresses his somewhat revolutionary ideas on the subject of psychic research and life after death. The continuation of this presidential address will appear in next week's issue.*—EDITOR.]

[1] For details of my experiment on this subject see Phil. Trans. Roy. Soc. for 1893 and 1897; or a very abbreviated reference to it, and to the other matters above mentioned in my small book "The Ether of Space."

[2] See, in the *Philosophical Magazine* for 1879, my article on "A Classification of the Forms of Energy."



The 32,000-ton floating dock leaving the Tyne for Sheerness.

"Dreadnought" Floating Dock for the British Battleships

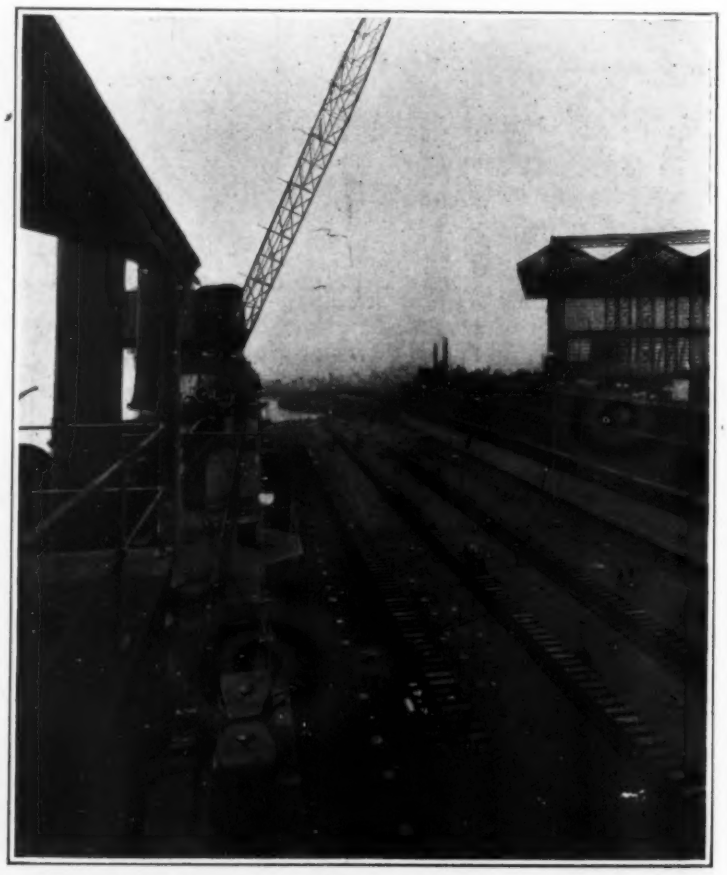
The Difference Between the "Box Dock" and Docks of the "Self-Docking Type"

By Frederick C. Coleman

SOME two years ago the British Admiralty decided upon the provision of two 32,000-ton floating docks for the accommodation of their "Dreadnought" and super-"Dreadnought" battleships. Orders for these two docks, one to be attached to the Chatham Dockyard and located at Saltpan Reach, in the River Medway, near Port Victoria, Sheerness, was ordered from Messrs. Swan, Hunter & Wigham Richardson (Limited) of Wallsend-on-Tyne; and the other, to be stationed at Portsmouth, was ordered from Messrs. Cammell, Laird & Co. (Limited) of Birkenhead. The Medway dock has been the first to be delivered, and this is illustrated in the accompanying engravings. The dock, like that for Portsmouth, has been built from the designs of Messrs. Clark & Standfield, of Westminster, and it is of the "box" type, with two side walls, that is to say, on each side of the pontoon proper and running almost the full length of it there is erected a side wall. Not only are these side walls permanently attached to the pontoon, but the dock cannot be taken apart in any other way. This broadly constitutes the difference between the "box" dock and docks of the "self-docking" type. The latter are built in detachable sections, so that one or more portions of the dock can raise the remainder for purposes of cleaning, painting, and repairing. The dock illustrated is 680 feet in length over platforms, 640 feet 0¾ inch in length over the pontoons and 144 feet 0¾ inch in width. The clear width between the rubbing timbers on the top deck is 113 feet. The side walls are 65 feet 6⅝ inches in height on the outside of the dock and 46 feet 5⅞ inches above the pontoon. In length, they are 520 feet 0¾ inch along the pontoon deck and 440 feet 0¼ inch along the top. The total area occupied by the dock is no less than 2¼ acres. We present a good view of an early stage in the construction, which shows the bottom plating entirely laid and some of the bulkheads of the bottom pontoon erected. The height of these bulkheads, or, in other words, the depth of the pontoon is 19 feet 6¾ inches. Overhead are shown the four great cantilever electric traveling cranes, which have proved invaluable in lifting material for the dock, and placing it in position. The houses in the background are on the site of the Roman camp, Segedunum, which was the easternmost stronghold of the great wall built by the Romans across Britain from the Solvay Firth to the Tyne. The actual wall's end was excavated in the shipyard of Messrs. Swan, Hunter & Wigham Richardson when the machine shop at the head of the floating dock berth was erected.

The weight of steel plates and angles worked into the dock amounts to about 12,000 tons. The keel blocks, of English oak, are spread over a length of 640 feet and the two lines of bilge blocks on each side cover a length of 280 feet. At the bow end of the dock there is a pair of flying gangways of lattice construction, giving access from one wall to the

The machine shop of the Medway floating dock for battleships.



View from top of starboard wall, showing the three lines of keel blocks.

View of interior of valve house; the gages show the height of water in the various compartments.

Bottom pontoon nearly completed, showing the heavy plating of the floor and the transverse members.

other. The mooring arrangements are unusually large and strong so as to efficiently hold the dock in a tide-way. At each end of each wall there is a strong timber roller-fender to assist in the guiding of vessels when being docked. Up the face of each wall are accommodation ladders giving access from the pontoon dock to the top of the walls. At the forward end of the starboard wall is placed the valvehouse, from which are controlled all the valves and pumping arrangements for the various compartments of the dock. We give an interior view of this valve house, which has long tables, on which are fixed a large number of pressure gages showing the height of the water in the various compartments of the dock. The valve operating gear is of the Westinghouse electro-pneumatic system, which has been in use for the working of points and signals on railways in all parts of the world since 1892 and has since been adopted for the operation of the water valves on floating docks. The presses are operated by air compressed to five or six atmospheres, and controlled by means of valves operated by an electro-magnet. When the magnet is energized, that is to say, after the slide lever in the valve house has been pulled over, the exhaust passage of the valve is closed and the inlet opened, and the air passes into the press and thereby lifts the hydraulic valve. The position of this apparatus is indicated back to the valve house by means of the circuit breaker, shown to the left of the press, the arm of which has the same travel as the press and hydraulic valve. All the time the magnet remains energized, the valve is lifted, but when the current is cut off by the movement of the slide lever in the valve house, the air is expelled by the weight of the valve and rod. Should the electric current fail, the electro-magnets can be operated by hand, and also, if the air pressure should fail, the valve can be opened by the hand-lifting gear provided above the stirrup of the press.

The bottom pontoon is divided both longitudinally and transversely by a number of watertight bulkheads and the two side walls each have a watertight deck running along their whole length. These bulkheads and decks divide the pontoon into about eighty watertight compartments. These are grouped into sections, each of which has its own set of valves, so that it can be flooded or emptied independently. Telephones connect the various machine spaces with the principal control station. In the port wall there is living accommodation for the dock master, the petty officers, and dock crew, and also mess-rooms, lavatories, etc. At each end of each wall are two steam boilers, each working at a pressure of 155 pounds per square inch, and all of these were built at the Neptune Works of Messrs. Swan, Hunter & Wigham Richardson (Limited). The pumping machinery comprises eight sets of compound diagonal type steam engines with eight sets of 16-inch vertical standard centrifugal pumps, working at 275 revolutions per minute.

In each wall are also placed two direct-acting Worthington steam pumps, capable of delivering 400 gallons of water a minute and these are intended for fire and wash-down service. In order to warp ships into position eight powerful steam-driven capstans are fitted on the walls, and there are also placed on the top of the walls two 5-ton electric cranes. In each wall is located a dynamo room. The machinery consists of duplicate sets of two-crank compound inclosed engines, running with forced lubrication at 400 revolutions per minute, and each driving a Westinghouse direct-current generator. The engines have cylinders 16 inches and 24 inches diameter by 10-inch stroke, and they are mounted on an under-base which also carries the generator. They are fitted with a shaft-throttle governor, also an emergency safety governor, which can be worked either by hand or automatically from the main governor when the speed increases 10 per cent. The pistons are fitted with restrained type piston rings. The piston rod and valve rods for both H. P. and L. P. cylinders are fitted with metallic packing. Each set is capable of developing 310 brake horse-power (210 kilowatts) as a normal load with 140 to 150 pounds steam pressure working non-condensing, an overload of 10 per cent for two hours with 110 pounds steam pressure, condensing or non-condensing, also to develop full load with 100 pounds steam pressure and 50 per cent overload for short periods with increased steam pressure. The dock has a fine equipment of electrical machinery which supplies current for driving the machinery in the workshops, the traveling cranes, the valve gear, lighting, etc., and also power and light for any warship that may be in the dock. At the top of the walls are placed large electric arc lamps hanging from revolving standards, and in addition to these there are numerous portable clusters of lamps. In each wall of the dock there is an air compressor which provides power for the electric pneumatic valve operating gear, and also pneumatic tools, of which there is a complete equipment. In the starboard wall, there is a complete range of workshops, comprising a smithy, lathe shop, machine shop, and coppersmiths' shop. In the smithy is a flanging machine, punching and shearing machines, smiths' forges, and a very effective 5-hundredweight power hammer.

In the lathe shop are five center high-speed lathes and one 6-foot chock lathe, and one horizontal boring and milling machine. In the machine shops are various machines for milling, drilling and planing, and also a belt-driven hack saw. In the coppersmiths' shop is a hydraulic copper pipe-bending machine and two coppersmiths' hearths. The dock left the Tyne in charge of the Dutch tugs "Roodezee" and "Zwartezee," belonging to Messrs. L. Smit & Co., of Rotterdam, and on the journey to the Medway the towing gear was thus composed: On the one part of the tug two heavy chain bridles were attached and onto this were spliced 4½-inch circumference specially flexible steel wires of a length of about 40 feet each. These wires were connected to extra superior manilla ropes, 18-inch circumference of 120 fathoms length. On the other end of the ropes there were again 4½-inch steel wires secured to the towing bits of the tugs. One of the photographs gives a picture showing the tug in course of delivery to Sheerness.

Practical Operation of Gas Engines Using Blast-Furnace Gas*

Purification of the Fuel Gas, and Other Important Factors

By Charles C. Sampson

THE question of the operation of gas engines using blast-furnace gas as fuel includes several important factors outside the actual operation of the engines themselves. It will therefore be aside from the present purpose to do more than state that the usual blast-furnace gas has the following composition:

	Per Cent
Carbon monoxide	23
Carbon dioxide	12
Hydrogen	2
Methane	2
Vapor of water	3
Nitrogen	58

and a calorific or heating value of about 900 cal. per cubic meters, and gives a consumption of 3 cubic meters per indicated horse-power in the engine.

CLEANING OF THE GAS.

One of the most important of these factors and one which held back the general use of these engines many years is the cleaning of the gas. As delivered by the furnaces to the downcomer the gas contains normally from 3 to 10 grains of dust per cubic foot of dry gas, but at times of slips or other sudden changes in the furnace, it carries much more. For use in engines the gas must be cleaned at most to 0.02 grains of dust to satisfy the requirements of the engine builders, but even this figure is too high to satisfy the operating engineer, since it is possible to clean the gas to 0.005 or 0.006 grains per cubic foot with great benefit to the engines.

The method of cleaning most used at present has three stages: (*a*) dry cleaning to 1½ to 2 grains per cubic foot which is always done by the blast-furance department; (*b*) primary washing in static washers to about 0.15 grains per cubic foot; (*c*) dynamic or mechanical cleaning in highly developed machines to 0.015 or less. The last stages are usually handled by the gas-engine departments, though as the furnace men realize more and more that a cleanliness of 0.2 grains per cubic foot or less is of great benefit to the stoves and boilers, they will take over the second stage, leaving only the final cleaning for the gas-engine department.

The dry cleaning is done in dry dust catchers, the standard design being a large diameter, vertical, cylindrical shell into which the gas enters tangentially near the top and leaves through a vertical outlet pipe which extends about two thirds down from the top. These dust catchers remove the heavier particles of dust, but their efficiency is only about 80 per cent as they pick up, or perhaps do not drop, the finer dust which is carried on by the upward current of gas to the outlet.

The refinement of design in dry cleaners has advanced materially in the past three or four years, as shown in the modern apparatus resulting from the careful study of the problem. One of the latest of these is the centrifugal dust catcher shown in Fig. 1. This device makes use of the centrifugal separation of dust from the gas as it passes inward through a cylindrical spiral opening into a dust basin at the bottom. The gas enters at the top of the outside, leaves at the top of the inner end of the spiral and passes upward

* Paper read before the American Society of Mechanical Engineers and published in its *Journal*.

through an extension of the pipe around which it is wrapped. The gas passes free of all obstructions at the upper end of the spiral while the dust separated drops to the bottom through the open end. There is no tendency for the gas to pick up the separated dust and carry it out as is the case in the older types of dry cleaners.

It is frequently found that sudden changes in the direction of flow of the gas, as at water seals or other necessary bends in the pipe, are quite efficient in the removal of the dust. In one case gas carrying about 5 grains per cubic foot passed through four sharp bends and gave all dust but about 2 grains per cubic foot. For this reason every part of the dry gas main where such bends are necessary can be made to assist materially in the cleaning of the gas, if pockets are added equipped with valves so that the dust can be conveniently removed.

Where long gas mains are necessary they can be made to add to the cleaning of the gas by building them in successive lengths with sufficient rise and fall to allow the dust to settle in pockets at the bottom angles for cleaning. If the gas for any reason moves slowly in a long main, the loss of heat through the pipe will probably reduce the temperature below the dew point, and thus condense some of the moisture carried with the gas from the furnace and cause the deposit of wet dust which adds greatly to the cleaning plant labor. This is especially apt to occur where two or more groups of furnaces supply one washing plant; the gas from the one with the lower top pressure will move slowly or even reverse its direction of flow at times, allowing excessive cooling and the resulting condensation. This condensation will begin when the temperature is reduced to 115 deg. to 120 deg. Fahr. and will of course give more trouble in winter when the condensed moisture will freeze in the dust valves and drips and require continual thawing to allow its removal.

It is possible to keep the gas mains clean without taking them out of service if they are equipped with sufficient openings to allow every part of the pipe to be reached with a stream from a high-pressure water system, and with valves or doors at all low points for the removal of the mud washed down. The mains near the furnace of course do not need this equipment, as they can easily be designed to make them entirely self-cleaning, while it is quite necessary that long mains where condensation may occur be so equipped.

The present primary washers (the first stage of wet cleaning) are of the static scrubber type and include all those in which the gas passes through a stationary shell without moving parts, the water for washing being supplied either in spray or sheets. The spray and hurdle, Mullen, baffle, and rain type scrubbers come under this classification.

The spray and hurdle system is preferred on account of its better distribution of water, and since it is self-cleaning it needs inspection only after long periods of operation. Several of these scrubbers have been opened after from one to three years' service, and in every case have been found perfectly clean and required no repairs whatever before being returned to service. The wood was in good condition, as it is continually wet and oxygen does not have access to it to start decay. In the rain or baffle types the gas is more apt to channel and travel up one side of the scrubber and the water down the other.

It is important to secure uniform distribution of the gas as well as of the water in any scrubber. For the inlet a cone above two thirds the diameter of the shell with a cone-shaped ring below it open in the center about one half the diameter of the shell will give good distribution. These should both slope about 45 deg. to keep the mud from remaining on them.

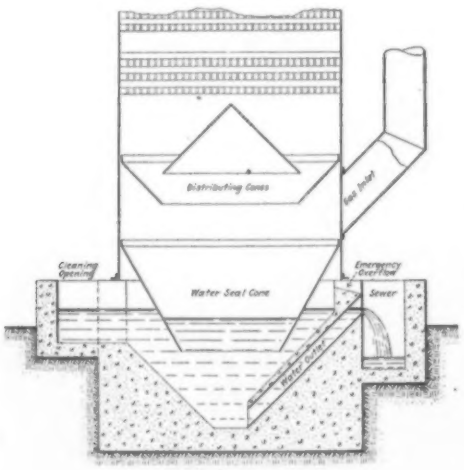


Fig. 2.—Scrubber bottom.

Two outlets at opposite sides of the top are better than one on account of the deflection of the water by the gas currents if only one is used. This is particularly true if the water is sprayed by falling on spray

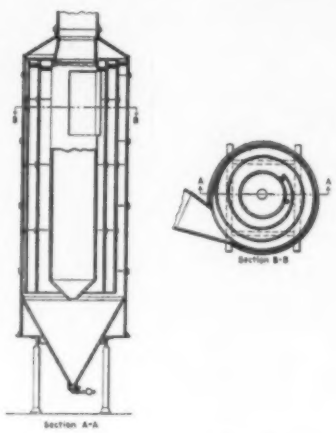


Fig. 1.—Centrifugal dust catcher.

plates as the gas current may then be strong enough to blow the water clear of the plate and thus entirely lose its effect. Spray nozzles are not subject to this fault, but are not able to handle water that has much dirt in it without a great amount of attention.

In designing the scrubber bottom, its foundation and the basin and overflow for the outlet water, it must be remembered that while the usual working pressure will be from 6 inches to 18 inches of water, a slip will give pressure of from 40 inches to 50 inches for a short time. A normal head of water of 36 inches from the bottom of the scrubber to the water overflow level with the basin walls 24 inches above this and an emergency overflow 4 inches below the top of the basin walls will care for slip pressure without blowing out any gas or overflowing the basin into the yard. The bottom of the basin wall will be self-cleaning if it has a steep slope and the outlet pipe is from the center of the bottom. The whole design of scrubber and basin must be examined to eliminate all places where mud can remain long enough to cake. Fig. 2 shows this arrangement of scrubber bottom.

Should the water overflow pipe be stopped even for a short time, the heavy mud will settle to the bottom of the basin, and when the overflow pipe is cleaned there will be such a quantity that even the extra head of water to the emergency overflow will not force it out. For this reason the forming of heavy chunks must be prevented as much as possible and provision must be made for stirring the basin water both with hoes or rakes and with a stream of water from the end of a pipe which can be thrust into all parts of it. It will be found convenient also to have the pipe bent at the end so that the stream can be directed up the overflow pipe to furnish additional head for starting the flow when necessary, or a special pipe with return bend and short nipple to thrust down the overflow pipe itself will surely be able to start the flow.

The final stage in cleaning is done with mechanical scrubbers or washers. These are highly developed and the Theisen patented gas washer has been in the lead for several years, though other types are now being worked out, their builders claiming better results with less water and power consumption than the Theisen. The Theisen washers require about 3 per cent of the power-plant output for their operation and from 16 to 18 gallons of water per 1,000 cubic feet of gas cleaned, which added to the 75 to 80 gallons required in the scrubbers makes the total from 90 to 100 gallons for the whole cleaning process. The newer apparatus, which are along the lines of the mechanical disintegrator, claim to use about 20 gallons of water per 1,000 cubic feet of gas for the whole cleaning process and to operate on less power than the Theisen washers.

HOLDERS.

In blast-furnace gas-engine plants the engines are entirely dependent upon the continuous supply of gas from the furnaces; a 100,000 cubic foot capacity holder can only be considered a pressure regulator with capacity for enough gas to allow retiring in good order when the gas supply is cut off for any reason. Thus in a 1,000-kilowatt plant with such a holder the gas on hand would operate the plant only for about 25 to 30 minutes and should not be counted on for more than 15 to 20 minutes. This in an emergency would give time to notify the various departments using power and allow them time to prepare for a shutdown.

The quantity of gas consumed by the engines is regulated by the governor to suit the power output, but since they must be supplied with gas at uniform pressure for satisfactory operation, it is necessary to regulate the gas supplied by some type of gasometer. This is best done by a gasometer of capacity such that the pressure fluctuations are not noticeable at the engines, and since it is well to have an emergency quantity of gas the gas holder itself will meet both demands at once if supplied with an efficient regulation valve. The holder will regulate the pressure perfectly between the maximum limit of the total quantity of gas that can be forced through the mains with the furnace pressure available assisted by the gas washers and the minimum limit of the leakage at the regulating valve.

There should also be the possibility of regulating the gas quantity at the secondary washers, since at times of very light loads the gas pressure between the holder and washer may blow out drip seals or cause dangerous leaks. This can be cared for by the installation of butterfly valves with quadrants either before or after the mechanical washers. The latter is to be preferred, for then the gas remains longer in the washers and receives additional cleaning.

A good regulating valve at the holder is a butterfly valve attached by means of levers and cables to the holder bell so that it will remain wide open until the bell rises within a few feet of its upper position, and close gradually till at the highest position it is completely closed. The arrangement shown in Fig. 3 works satisfactorily. The weight *A* must be heavy enough to close the valve and the weight *B* must be heavy enough to open the valve and also lift the weight *A*.

All exposed water lines must be protected from freezing. This is especially true of the supply to seals, drips from the gas main, and any line that does not have a continuous flow. With good water separators after the secondary cleaning apparatus, freezing weather or even 8 deg. or 10 deg. Fahr. below zero, will not cause trouble in the gas mains themselves, though any valves which may be nearly closed or which are closed part of the time must be carefully protected. The butterfly valve for regulating the gas should be inclosed in a tight box with steam coils to keep it in working order. This also is true of the valves at the gas-washing plant unless it is possible to install them within a heated building.

The water in the gas holder must also be warmed. The exhaust from the regulating valve coil will easily keep the holder water warm enough to prevent freezing except in the coldest weather (under 0 deg. Fahr.), when it is usually necessary to supply additional steam through several nozzles arranged to set up a circulation of the water around the tank. These should be well down in the water or ice will form on the lower part of the shell and build in toward the center and prevent the lowering of the bell.

During the time the holder water is warmed it is important frequently to observe its temperature, if too hot it will charge the gas with water so that condensation and freezing will take place in the gas-engine supply pipes. When the water circulates properly in the holder it is not necessary to have it any warmer than 38 deg. or 40 deg. Fahr., while a rise to 65 degrees or 70 degrees will give trouble.

If the gas holder is not visible from the gas-washing plant the operator needs a visible signal to give him its position, also an audible signal to inform him if it should lower beyond safe working position, the amount of the drop allowable before the audible signal operates being determined by the position of the regulating valve at the holder. The drop should be less than an amount to give a complete opening of the valve. The gas-washer operator should have telephone connections with the engine room, besides the usual whistle or bell signals which are used to notify him of the starting or stopping of engines. He should also be in close touch with the blast-furnace department in order that any change in the gas supply can be known in advance.

RELIEF DOORS.

In all gas-pipe lines so-called explosion doors are installed. These are as a rule useful only for access to the main for cleaning, usually being made of cast iron

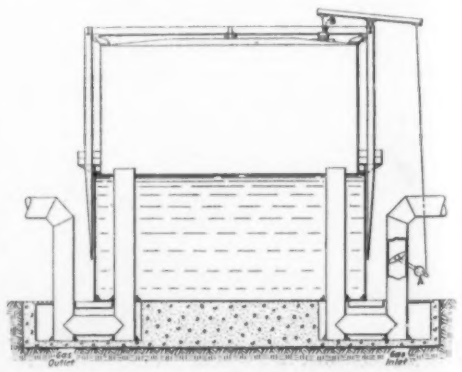


Fig. 3.—Arrangement of regulating valve for gas holder.

and hinged; on account of their weight and method of attachment the moment of inertia is so great that they will not open quickly enough to prevent the destruction

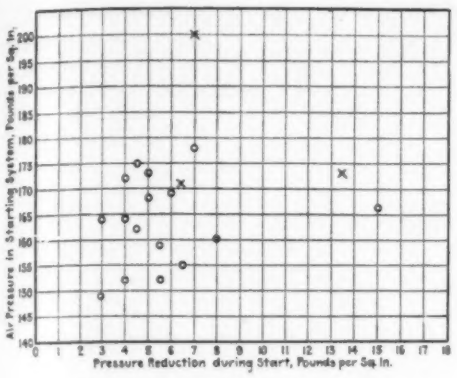


Fig. 4.—Record of pressure drop.

of the main in which they are installed. Any gas main that will support itself over the span usually employed will easily stand any pressure that can be produced in the cleaning plant, and the use of these valves or other relief valves is not necessary. The inconvenience of escaping gas makes it advisable to design them as cleaning doors only, and to arrange them with a clamp fastening to avoid this inconvenience. If it is thought necessary to instal explosion doors or valves I would suggest the use of sheets of light material arranged in frames so that they will be blown out should an explosion occur in the main.

The best protection from explosions is careful operation, especially to guard against a reduction of pressure of gas at the furnace side of the cleaning plant due to no air being drawn into the main at the stoves, and to see that no piece of apparatus is put in service with air trapped so it can be mixed with the gas and sent along to the engines.

ENGINE STARTING.

A most important factor in successful gas-engine operation is good engine operators, and the same characteristics which are valuable in steam-engine operators are valuable in the gas-engine engineer.

The operation of the engines themselves is exactly similar as far as the running gear is concerned, and it is only the fact that the gas engineer is fireman as well as engineer that makes it necessary that he be more alert and watchful. Economical operation of gas engines on the same account requires that the engine operator must have his sense of "the feel of the machine" well developed.

Compressed air at from 150 to 200 pounds per square inch pressure has proved satisfactory for starting gas engines and is especially desirable on account of the ease with which a suitable quantity can be stored under pressure ready for use at any time.

In a starting system of 2,000 cubic feet capacity the air pressure is lowered about 20 pounds in starting one 3,000-kilowatt twin-tandem unit, and since 150 pounds pressure is sufficient for a start there is a possibility of at least three starts from 200 pounds initial pressure, which is certainly sufficient to get under way even during the excitement of an emergency shutdown.

Record was kept of the pressure drop in starting a 1,800 horse-power twin-tandem Allis-Chalmers engine from an air system having two tanks of 1,100 cubic feet capacity each. This record included 19 starts, 16 using the full capacity of the system and three with one tank out of service. This record is plotted in Fig. 4, the pressure in the system being shown as ordinates and the pressure drop as abscissæ; the 16 starts with complete air system in use are indicated by circles and the three that were made with one of the air tanks shut off, by crosses. It may be noted that the quantity of air required to start the engine was about the same, regardless of the pressure in the air tanks.

The necessary capacity of air tanks and air compressors for a given plant depends upon the number and size of engine units, and the frequency with which they may need to be started. After the engine operator becomes familiar with the operating peculiarities of the engines he should be able to start them at intervals of from 4 to 8 minutes and not lower the air pressure more than the compressor can make up in that time, if an engine lowers the pressure 8 pounds per square inch in a 2,000 cubic foot capacity system, the compressors should compress 8/15 of 2,000 = 1,060 cubic feet free air in the maximum time allowable between starts, or say 10 minutes. This would require two 106 cubic foot compressors.

For the ordinary blast-furnace gas-engine plant of from three to six engines two air compressors of 100 cubic feet capacity and air tank capacity of 2,000 cubic feet are quite sufficient, while for more than six engines the compressor capacity should be increased rather than the tank volume. At least one of the compressors must derive its power from some source outside of the gas engine in order to be able to start the plant if all units should be down.

It is important to keep the water jackets thoroughly clean and the item of jacket cleaning should appear regularly in the engine operation schedule. This cleaning requires careful attention since, with the class of labor usually put on this work, it will be slighted in the places where the most care is needed.

LUBRICATION, CLEANING OIL.

The question of lubrication is one of so many variations I can only say that for general lubrication of such as main bearings, crosshead and crankpins and crosshead slides where the rubbing surfaces are at room temperature, an oil of the following physical characteristics has given excellent service:

Specific gravity	888
Viscosity (Tagliabue)	210 at 70 deg. Fahr.
Cold test	35 deg. Fahr.
Flash temperature	435

This service also includes satisfactory separation of water and dirt by settling and filtration. On account of the almost certain mixing of water from the cooling system with the system oil, it is necessary to provide means of separating the water and oil in the filtration process and it can be done thoroughly only by heating the oil to about 160 deg. or 190 deg. Fahr. and giving it time in a quiet condition to allow the separation. A large part of the dirt will settle with the water. Such that does not, must be removed by filtration through fine cloth, either of organic fiber or of fine wire. The latter is more to be desired because of the ease with which it can be cleaned.

A good oil-cleaning system giving excellent satisfaction consists of one 1,500-gallon water-separating tank, shown in Fig. 5, with a heating coil over which the oil flows as it enters on returning from the engines, and an adjustable automatic water overflow to discharge the separated water, two settling tanks of the same size through which the oil passes in tandem to allow time for quiet settling of dirt particles, and a filter unit with 20 filter bags, 10 each in two filter tanks.

An extra tank is used when either of the other three is out of service for cleaning. An auxiliary tank of about 200 gallons capacity is used for "boiling up" the sludge taken from either of the large tanks or the filters at time of cleaning as well as such dirty oil as can be drawn off daily from the bottom of the overhead oil tank.

This system is shown in Fig. 6. The oil from the engine drips enters tank *A* over the steam coil, flows down through the inner cone then up and out the overflow to *C* and *D*, thence to the filters *F* and *G* through *E*, which is also a water separator. The clean oil is pumped from the filters by one of the pumps at *K*, which are in duplicate, to the overhead engine supply tank in which the quantity of oil on hand is shown by an index on a large gage visible from the engine-room floor. Gage glasses on each tank show the level of the line between the oil and water both as an operating convenience and as a means of checking the quantity of oil used during the month. The separated water flows down the inside of the cone in *A* to the bottom of the tank from which it flows through the automatic overflow *H*. The nipple in the tee at *H* is adjustable so that the water in *A* can be held at the level found best in operation.

A part of the dirt is oil-coated so that it floats between the water and the oil and will accumulate until its removal is necessary. The oil from the engines is then turned into tank *B*, the supply to *C* and *D* being kept up by stopping the water overflow and filling *A* with water as long as good oil flows out. The water

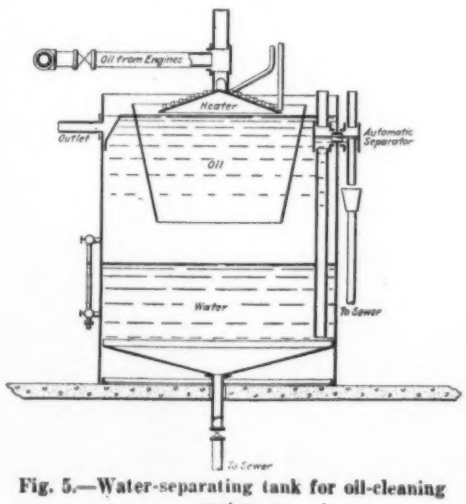


Fig. 5.—Water-separating tank for oil-cleaning system.

is then drawn off to the sewer and the sludge pumped into the boiling tank *J*, where as much oil is reclaimed as possible. The other tanks are cleaned in the same

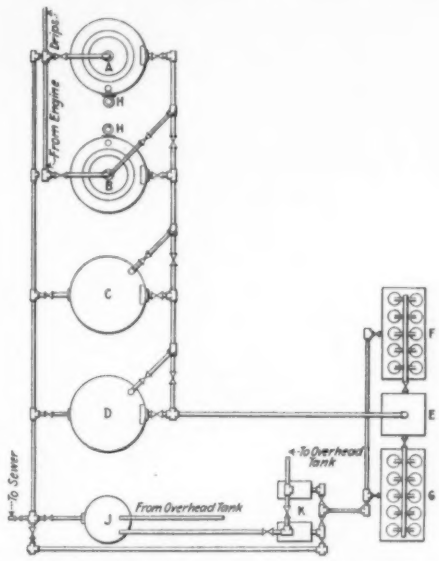


Fig. 6.—Oil-cleaning system; A and B, water-separating tanks; F and G, filters; J, boiling tank.

way. There are pipe connections from the bottom of all tanks to one of the pumps, also from the discharge of this pump to the tank *J*.

Such an oil system will keep the oil clean for a plant circulating 500 to 600 gallons per hour. Of course some oil is lost through leakage at the engines, and some is wiped up in keeping the engines clean, but the addition of new oil need not amount to more than 100 gallons per month. In blowing-engine plants where the engine oil is drawn into the blowing cylinders from mechanically operated valves the oil consumption will not be so low unless good separators are installed in the cold blast mains to discharge this oil back into the system.

The cylinder oil question is also one of many opinions. The varying cleanliness of the gas, hardness of cylinder walls and piston rings, piston speeds, mean effective and maximum pressures all have their influence on the action of the cylinder oil. An oil showing a specific gravity of 0.902; viscosity (Tagliabue) of 78 at 212 deg. Fahr., and a flash temperature of 380, gave excellent results in a gas blowing-engine plant where the dust was low (0.01 or less) and piston speeds less than 600 feet per minute, and was not satisfactory in another, with 0.012 dust and piston speeds of 850 feet per minute. In the latter case the oil was replaced by one of specific gravity, 0.920; viscosity, 203 at 212 deg. Fahr., and flash temperature, 502, and immediate improvement was shown.

With the lighter oil the cylinders were not dry in any part, though they did show more wear than was expected for the time in service, the machining marks being almost invisible after three months' operation.

The cylinder oil can be put in a tank in the basement and piped to all cylinder oil pumps by using compressed air at 15 pounds per square inch. This provides opportunity for the installation of oil meters to keep accurate account of the oil used on each engine, or the supply tank may be equipped with graduated gage glass and record kept of the supply to the whole plant.

IGNITION.

The mechanically operated igniter is much to be preferred over the magnetic type. The current supply should be from a source not liable to fluctuation, such as that from a motor generator set that supplies current to the ignition system alone and arranged in connection with a storage battery so that should anything happen to the motor generators the battery would take up the load, automatically signaling the operator. The location of the ignition plugs is important, since an explosion on one side only of the piston will force it to the other side and cause it to strike the cylinder wall.

Premature ignition is usually caused by excess hydrogen in the gas, and will occur when the quantity of hydrogen reaches 4.6 per cent, depending also upon the cleanliness of the cylinders. This prematuring is one of the first indications of leaking cooling plates in the furnace and the gas-engine operator will often be able to inform the furnaces of this condition before they learn of it themselves. When a furnace has the wind off for casting, the water pressure in the cooling plates is greater than the furnace pressure and the water enters the furnace and is immediately dissociated, the oxygen being consumed by the coke leaves the excess hydrogen in the gas. When the wind is put on again this gas, rich in hydrogen, is sent along to the engine causing prematuring.

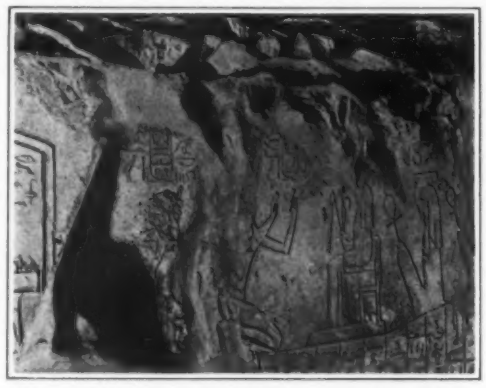
Tablet from the passageway. King Merenptah in the hall of the forty-two witnesses makes confession. (Book of the Dead Chapter 125.)

Boys emerging from a cutting to empty their baskets on the cars near the village of El Arabah.

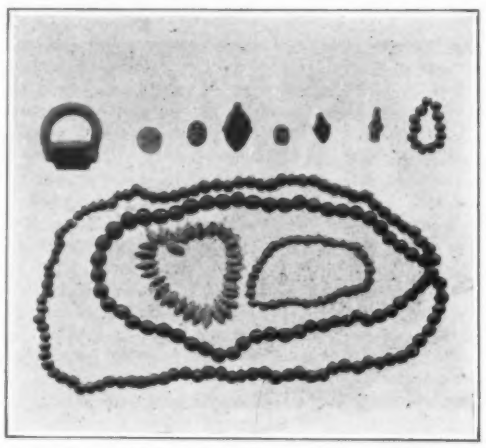
Progress in Egyptian Exploration

Important Disclosures are Expected in the Near Future

By M. N. Buckman*



On the left the Ba of the king represented as a bird with a human face. On the right a picture of the king adoring three deities.



Amulets, necklaces and other ornaments for personal wear.

Clearing the sand from the south end of the main hall. The walls of the Osireion are just appearing about on a line with Mr. Nevill's helmet.

On the west bank of the Nile, one hundred miles below Thebes, near the present Arabat el-Madfuneh, is the site of ancient Abydos. Once second only to Thebes, it is one of the holy spots of Egypt. Here are the ruins of the Temple of Seti I with its famous King-list, fragments of a temple by Ramses II, and a city of tombs. Here, in 1818, Bankes discovered a tablet showing 26 royal names, and here, in 1865, Masiette discovered a still longer, the famous King-list of Abydos, with 76 cartouches. Excavations were carried on later by Amelineau in 1898, by Petrie in 1899, followed the next year by Miss Murray.

Cut into the marl underneath the desert surface, within the temenos area and leading toward the temple itself, was discovered a subterranean hall, its walls covered with texts from the Book of the Dead. The name of Merenptah appears, son of Ramses II.

Work in the '80's developed a doorway, presumably opening into a passageway leading whither? To a temple? To a temple of Osiris? Would it prove a tomb of the god?

Here in 1909-1911 the Egypt Exploration Fund resumed work under the direction of Prof. Naville. Behind the doorway in question appeared a sloping passageway of whose ceiling of nine-foot monoliths only one remains. Historical research points to an ancient temple of Osiris here on the edge of the desert as early as the sixth dynasty and possibly before the first. Around this grew up a town with its burials, continuing to the fourth or even fifth dynasty. Following the sixth dynasty there was erected a large inclosing wall, of which remains still exist, some distance outside the temple ground. In a corner of this area occurred interments of dynasties from the eleventh to the seventeenth. The inner inclosing wall, twenty feet thick, and its huge red granite pylon, date to the eighteenth dynasty. The rebuilding of the outer wall dates probably to the twentieth dynasty. The temple itself was rebuilt in the twenty-sixth dynasty and enlarged in the thirtieth. Thus, as often, a series of towns and restorations lay piled up in succeeding layers. "We have, then," says Prof. Petrie, "to deal with what was a series of towns piled up in strata which are usually six inches to a foot thick." The inscriptions cover, with intervals, a period from the sixth to the thirtieth dynasty.

Interest especially attaches to this site in that it is the seat of the Osiris cult. Osiris the half divine, half human, taught his subjects the arts of civilization. For this he was brutally murdered by the god Set and his companions. The mutilated body of Osiris (according to the later account, his head only) was buried at Abydos, the Greek form of Abdu (Abidu), "Mound of the Osiris-head Emblem." Hence, the early kings of the province of Thinis desire their burial to be at holy Abydos. This great temple site, then, awaits exploration, the ground of the earliest temple, that of the god Osiris.

On the walls of the passageway are chapters from the Book of the Dead and vignettes of King Merenptah, of which one represents the monarch at a game of draughts. After a distance of fourteen meters the sloping passage became horizontal again with chambers on the sides. The explorers were up to a doorway topped by a fifteen-foot lintel. But it was a blind door in the end of a heavy wall twelve feet thick, separating two rooms of which one, about twelve meters by five, and four and a half meters high, has now been cleared. The structure seems to have been a Mastaba, whose walls possibly projected above ground. Four rooms have been

*Secretary of the Egypt Exploration Fund.

Two figures of mummified king.

King Merenptah playing draughts.

located of which one has been entirely cleared.

But Merenptah was buried at Thebes. This, then, is a sham tomb of Merenptah. But there are difficulties:

1. There is the word of Strabo.

2. There are traces of hasty occupation. The walls are painted, not sculptured. The inscriptions and figures are not even outlined in colors as in unfinished tombs elsewhere. There are no traces of intentions to sculpture. The general appearance of the walls antedates the XIX dynasty, possibly dates to the XII dynasty.

3. There is a lack of order in the arrangement of inscriptions. The arrangement is not studied and systematic. Everything bespeaks haste.

4. The solution will appear when the end of the series of chambers and passageways is reached under the temple of Seti.

5. Present indications go to show that Merenptah desiring a tomb where his Ka might rest near the Sanctuary of Osiris, appropriated an earlier tomb.

Whose was this earlier tomb? Is the sanctuary whither things seem to be tending the famous, the traditional tomb of Osiris? The uniqueness of the construction, the focusing of legend, and the character of and arrangement of mural decorations surely warrant anticipations.

The past season has been busy, though not rich in spectacular results. The huge mound of debris left by Mariette, in the early days of Egyptology when no one dreamed of the scope of the undertaking, has taxed resources heavily. The Director of the Service des Antiquites, Prof. Maspero, realizes the importance of the site and is lending assistance.

The Exploration Fund has prepared the ground for what is hoped to be the final campaign. What will appear when the complex passageway terminates, as would now seem, under the Temple of Seti, long famed for its King-list and now a pleasant resort for tourists? To this end all energies are bending and funds are being collected. It is worth every sou it costs, all the effort and sacrifice. And if scholars divine aright, the inmost mystery of Egypt's religion will ere long be brought to the light.

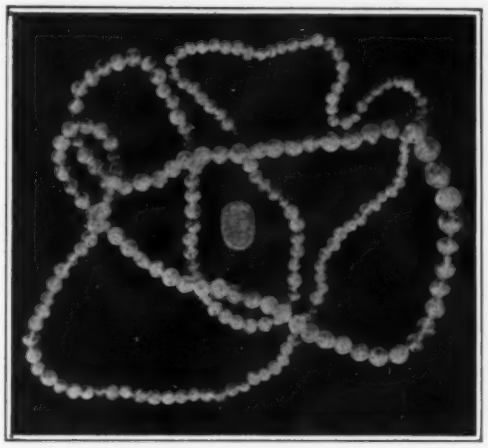
Noise and Factory Efficiency

A LARGE part of the noise in a manufacturing plant may be translated into loss of power, unnecessarily rapid depreciation of equipment, and a reduced efficiency of employees resulting from the distraction which is created and from the indirect effect upon physical health. Many users of machinery have awakened to the fact that their manufacturing rooms should be as quiet as possible and in selecting new equipment have had this in mind. Some operations cannot be performed without disturbing sounds. The press and the hammer must strike a blow; the circular saw and the knives of the table planing machine must shriek their way through the material. But the belts and gearing and other parts of the mechanism need not add to the necessary noises until there is a bedlam of unpleasant vibration.

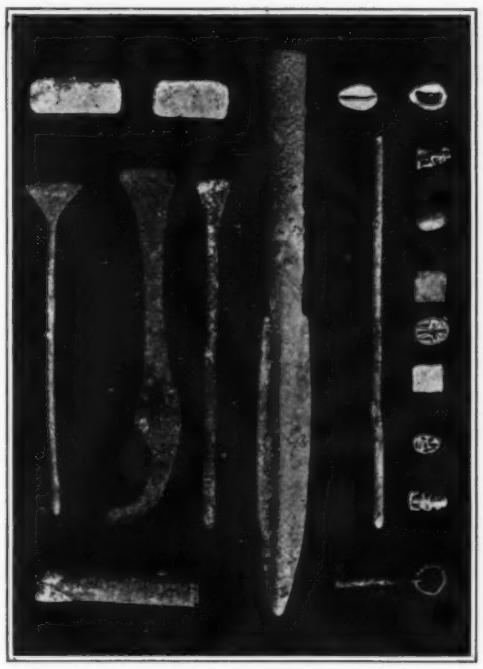
Some machinery designers have gone ahead rapidly in making improvements in this respect. Indeed, a great deal of information is available, for there has been much scientifically directed research, the result of which is no secret. The primary purpose was to reduce loss of power and prolong the useful life of the machine by eliminating friction. The secondary and hardly less important advantage achieved is a nearer approach to quiet. A striking example is given in a paper recently prepared by E. P. Bullard, Jr. Investigations which he directed at his works in Bridgeport, Conn., proved that gears running above 600 peripheral feet a minute are liable to be noisy, whereas gears running under that speed are quiet. The text books put 1,200 feet as a limit, he explained, and automobile designers run gears up to 2,000 feet at times, but on a low gear and at maximum engine speed.

To produce quiet running at the higher speeds, the gears must be most perfectly fashioned. In some of the machinery produced to-day the gear speeds are excessive when compared with the accuracy of the machining, and they are consequently noisy, and the fault increases with use.

Another typical factor of design which may lead to noisiness, through frictional troubles, is that of lubrication. The oil can is losing its importance where well designed machinery is used. This is a most excellent change, for the possible troubles due to carelessness and neglect are done away with. Automatic lubrication replaces many oil holes. These are only examples of the possibilities of design which make themselves known by noiseless running.—*The Iron Age.*



Amethyst beads. Chain about four feet long. Probably one of the finest specimens of ancient jewelry ever found in Egypt.



A number of small bronze objects.

Heat and Energy Expended by the Human Motor

ON an average an adult human being dissipates about 2.5 kilowatt hours of energy per day to effect his various muscular actions and to maintain a body temperature superior to that of his surroundings, the loss by radiation having to be continually made good.

The power thus continually expended is 100 watts or about 1/7 of a horse-power. Of this the loss by radiation constitutes about one half, that is to say, about 50 watts. The human body exerts about the same heating effects upon its surroundings as a 16 candle-power carbon filament lamp.

Art in Natural* History

A Striking Elephant Group at the American Museum of Natural History

"The Last Stand."

Model by Mr. Carl E. Akeley for elephant bronze. (Photo one eighth size of model.)

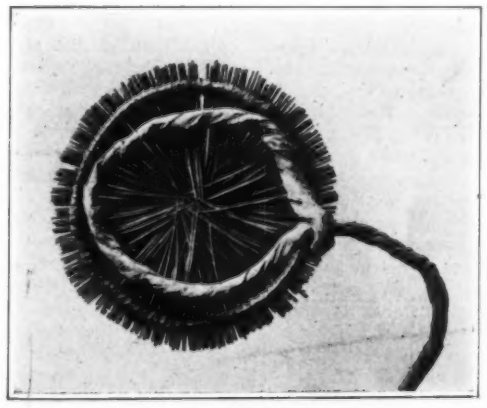
WORK on the elephant group planned by Mr. Carl E. Akeley for the American Museum is now under way. Many studies are already in progress both for the group and for supplementary miniature groups and single figures to be cast in bronze and used to supplement the life size group, thus illustrating in full the character and habits of the African elephant.

Some of Mr. Akeley's work is to be seen in the Chicago Field Museum, a series of groups of African mammals, a very beautiful seasonal series of the Virginia deer and as the central piece of the Museum a statuesque group of two elephants. At present Mr. Akeley has connection with the Field Museum in an extension of the African mammal series, working at the moment on an African buffalo group of large proportions.

The elephant group planned for the American Museum, a family group of massed elephants, five in number, is destined for the center of the African hall in the proposed new wing. The group, statuesque in effect, without habitat, will tower eighteen feet from the floor, elevated four feet on a pedestal base in order to give an unobstructed view on first approach from the ends of the hall over two low groups of rhinos one at either end. These three groups in a space 44 by 136 feet will be mounted according to Mr. Akeley's newly devised method for non-haired mammals which gives them the permanency of bronze and allows exhibition without cases, exposed to the varying heat and humidity of the open hall.

The elephant group will have in addition to the correlated bronze miniature groups and single figures already mentioned, bas-reliefs in bronze on the sides of the pedestal. These will show the massing of the animals in herds, and other features of the story of the African elephant and its relation to the country and to the natives. As planned, the great central space of the hall with its elephant and rhino groups will be encircled by a series of thirty-two panoramic groups with habitats and painted backgrounds, each composite in character so that together they will show several hundred species. The corner groups for instance will represent the Congo forest (okapi the center of interest), African plains, African desert with typical water-hole (giraffe the center), and a river scene of Africa. Each of these will contain many species, the last for example, crocodiles, hippos and turtles in the water, and in the trees that border the river different species of monkeys and birds. These thirty-two groups will be in cases so constructed as to be under automatic control regarding light, temperature and humidity, entirely independent of the varying conditions in the main open part of the hall.

Two requisites underlie successful work in taxidermy, as the mounting of animals for museum exhibition is known, in addition to accuracy of the scientific truth to be demonstrated. The first of these is technique of such character that not only is the amount flawless in workmanship but it is fitted also to endure unchanged for



An elephant trap.

Consists of a "basket," and a slip-noose of rawhide placed over a hole dug in the trail.

* Reproduced from the *American Museum Journal.*

many years, fifty, one hundred, surely even longer. For in this age of advanced experiment and knowledge such a result alone justifies the money and effort. Still more important than money and effort however, is the fact that the animal life of the globe in its wild state, especially the large mammal life, is in very large part approaching extinction because of the encroachments of civilization. For this reason, museum records made to-day should be historical in that they embody accurate knowledge in permanent form for the future. Also it chances that the knowledge which can be put in the graphic form of groups is precisely that part of zoological science which it is most important to-day to preserve, namely, field knowledge or ecological records, the interrelationships of any given race of animals with other races and with environment, which if not gained in the near future will be lost forever. Collections are important (and they too must be put into shape for enduring) and they must be made in large series before too late. Work on them however, with the systematic, anatomical and comparative results which in combination are of such intrinsic value in the general body of science, will not be injured or lost by delay.

The demands of the time in the matter of ecological record are strong upon museums and particularly upon the American Museum which aims in so large a degree to put its information in graphic form because of the enhanced educational value. Therefore that the opportunity seems at hand when Mr. Akeley will give his power as a taxidermist to express his large field knowledge of African mammals, is a triumph for science even in greater degree than for taxidermy or for the development of the American Museum, in the advancement of art in natural history.

But there is a second requisite for the adequate mounting of animals. It lies in a combination of the life and of art, a choice of life facts, positions, relations such as can be set forth in accordance with what we recognize as artistic effect. The taxidermist who can produce flawless and relatively enduring technique is rare; the man who combines with these the second requirement is still more rare.

Lenard's Researches on Phosphorescence*

The Phenomenon Probably Due to the Photoelectric Action of Light on Atoms of the Active Constituents

By E. N. Da C. Andrade, B.Sc., Ph.D.

When ordinary bodies are heated, they begin to emit visible light at a definite temperature, which is the same whatever the substance may be (about 500 deg. Cent.); it is to such radiation, due to temperature alone and usually referred to as temperature radiation, that Kirchoff's law applies, though W. Wien (*Nobel-Vortrag*, 1911, p. 5) imagines that it may be possible to extend the law to other radiations by an extension of the conception of temperature; he admits, however, that at present it is impossible to state how, for example, a phosphorescent body can fall into equilibrium with the radiation. In certain cases light may be emitted at a temperature far below that at which temperature radiation sets in; such cases are classed together as luminescence phenomena; these are variously grouped under the headings triboluminescence. lyoluminescence, crystalloluminescence, chemical luminescence and phosphorescence, fluorescence and thermoluminescence. The first three names are given respectively to the emission of light which takes place on rubbing or breaking certain substances (a well-known case being that of sugar), to the emission of light observed when certain solid substances are dissolved, and to the emission of light attending the crystallization of salts—for instance, sodium or potassium sulphate. It is probable that the last two cases are only examples of triboluminescence, the light being attributable to the friction and breaking of the crystals which take place on dissolution and crystallization: apparently the bodies which exhibit the phenomena in question are all triboluminescent. Chemical luminescence is the form of luminosity accompanying certain chemical actions, such as slow oxidations: the so-called "phosphorescence" of phosphorus and of putrefying organic matter are cases in point.

The term phosphorescence is properly applied to the power which many bodies possess of emitting light after excitation by radiations. This excitation can be effected not only by visible and invisible (ultra-violet) light but also by cathode and canal rays and by Röntgen rays; irradiation of some kind is necessary, however, in all cases of true phosphorescence.

In phosphorescence, the emission of light continues after the exciting radiations have ceased; if the emission does not persist during a measurable time the phenomenon is termed fluorescence. In the case of solids there is no true fluorescence, although the term is often used in speaking of the phosphorescence of very short duration which is exhibited by many solids: in the case of gases and liquids the duration of the period of after-glow is inappreciable and we may speak of fluorescence. But there is little point in attempting to distinguish rigidly between the two terms, though it is possible that more refined measurement would show a very short after-glow even in the case of gases. Thermoluminescence, so called by E. Wiedemann, who first observed it, is the property of selective light-emission which certain artificial substances exhibit on being heated to a temperature far below that which conditions temperature radiation; it is necessary to excite the substance previously by certain radiations, which do not, however, cause the emission of light at ordinary temperatures. This is only a particular case of phosphorescence, the exciting energy being stored at the lower temperature and only liberated as the transformed radiation at the higher: all the phosphoroids—as we shall in future call phosphorescent solids—prepared by Lenard can be caused to show such a storage of energy. Hence we shall include the so-called fluorescence of solids and thermoluminescence under the general term phosphorescence.

Lenard, in conjunction with Klatt, first stated in detail the conditions to be observed in preparing phosphoroids from the alkaline earths and systematically prepared a large number of substances of this class, which includes nearly all those which remain luminous during a considerable period after the exciting light has ceased; a form of luminosity which it is convenient to call the after-glow. Three components are necessary: the sulphide of an alkaline metal; a small quantity—generally less than a ten-thousandth of the whole—of a foreign metal; and a fusible component or flux. The action of the flux, which may be any one of a large number of colorless fusible salts, sodium sulphate for instance, is principally to bind the loose mass together; it has also an influence on the intensity of the emitted light which will be further referred to.

The specific character of the phosphorescent light is dependent on the presence and nature of the traces of foreign metal. Lenard and Klatt were able to attribute the phosphorescence of calcium sulphide previously investigated by Lommel definitely to traces of particular metals. To each metal corresponds a series of emission bands, the phosphorescent light being always resolved by the spectroscope into bands having a maximum of intensity at a given wave-length fading off into darkness on both sides of this maximum. The bands are referred to by the wave-length at which they have their maximum intensity; and uncertainty as to the identity of a given band, which might arise in the discussion of the displacement of a band by influences to be mentioned later, is avoided by the definition of band as a complex of emitted wave-lengths which possess common properties in respect of temperature, excitation by light of a particular wave-length, and rate of decay after the exciting light has been cut off. These tests also serve to separate superposed bands. The spectral position of the bands is peculiar to the given active metal, but their intensity and period of decay depend to some extent on the fusible component. A pure phosphoroid is defined as consisting of one alkaline sulphide together with traces of an active foreign metal and a flux. The pure sulphides do not phosphoresce, but an addition of 0.002 per cent of bismuth will render barium sulphide strongly phosphorescent. The color of the phosphorescent light varies markedly with the temperature of the phosphoroid, the shade obvious to the naked eye being made up of different bands which all vary in intensity independently of one another with temperature. In the case of each phosphoroid, there is a temperature above which it cannot be excited, but there seems to be no lower limit in this respect.

The investigation of phosphorescence has been greatly facilitated by Lenard's method of plotting the distribution of the exciting and excited light in the spectrum. As long as the phosphorescent glow was treated as a whole, the complexity of the observed phenomena baffled interpretation, but the behavior of the individual bands is not so incomprehensible. To observe the distribution of excitation, in other words, the relation between the wave-length of the exciting light and the intensity of the incited light, a spectrum is allowed to fall upon a screen covered with the given phosphoroid, the exciting light from a Nernst lamp or mercury vapor lamp being passed through a quartz prism in order to obtain the ultra-violet portion strong and well dispersed. The parts of the spectrum which are most effective in exciting the phosphorescent light were then at once observable. On examining the incited light through a prism, using the method of crossed spectra, it is resolved into its component bands, the relative intensity of the different parts of which can be estimated. Stokes's law, that the incited light is of longer wave-length than the exciting light, is always obeyed by phosphoroids. As a first result of this method, it appeared that to each band of emitted light correspond definite ranges of wave-lengths which are capable of exciting it; these selective groups of wave-lengths will be referred to as the exciting spectrum. The composition of this spectrum depends only on the nature of the active metal and of the alkaline sulphide. Further, there are no bands common to different metals, either of excitation or emission. In Fig. 1 the spectral distribution of the exciting and incited light is set out according to Lenard's method in the case of the two phosphoroids calcium sulphide containing copper as the active metal denoted by CaCu and strontium sulphide containing copper denoted by SrCu. The sharp unshaded curves indicate the distribution of the exciting light, the abscissæ representing the wave-length of the light, the ordinates the efficiency of each wave-length in exciting the particular band of phosphorescent light in question—that is to say, the intensity of the incited light. The distribution of the intensity of the incited light according to wave-length is represented by the shaded curves. The first phosphoroid gives three bands of emitted light; these are represented separately, as there is a different exciting spectrum corresponding to each band; the three spectra are denoted by α, β, γ. The second has two bands, α and β, represented in the same manner. It will be observed that the bands are best excited by very narrow groups of wave-lengths and that in general more than one exciting band—usually three—correspond to each band of emitted light. The dotted curve gives the distribution of exciting light corresponding to the momentary process, to be referred to subsequently. The intensities of the different bands in the diagram are not drawn to scale, but they are all represented as having the same maximum intensity; this is done because, though all the bands have perfectly definite spectral positions, their relative intensities vary with the fusible component, the temperature and the manner in which the phosphoroid is prepared. Hence such a diagram can only give the general course, the position of the maximum intensity, and the range of each band.

The behavior of a band with regard to temperature is such that it is possible to discriminate between three different states of the phosphoroid. In the coldest state, which Lenard calls the lower momentary state, each particular band rapidly reaches its maximum intensity when incited, and on the cessation of the exciting light as rapidly decays—it being a general rule that a band which is easily incited dies out quickly, and that one which is slowly incited dies out slowly. The light emitted at this stage is often very feeble, sometimes not noticeable; as the temperature of the phosphoroid is raised, the second or "resting" state is reached, in which light energy is both emitted and at the same time stored up; when the exciting illumination is cut off, the stored-up energy is liberated as the after-glow, the intensity of the bands gradually diminishing with time. On raising the temperature still further the third temperature state, the upper momentary state, is reached, in which, as in the lower state, there is no after-glow, but a rapid excitation followed by a rapid emission of light. It is necessary, however, to distinguish clearly between the upper and the lower momentary states. In the lower state, besides the rapid emission, which is usually feeble, there is always an invisible storage of light-energy proceeding simultaneously, the which energy is liberated as a strong after-glow when the temperature of the phosphoroid is raised to that of the permanent state without subjecting it to further excitation. The energy thus stored in the lower state, which does not give rise to any luminosity so long as the temperature is below that of the permanent state, can be preserved during an extraordinarily long time, extending into months. The bands which appear at a given temperature are those which are permanent bands at that temperature. All luminosities which were observed by early experimenters to appear in phosphoroids on heating were due to energy having been stored in this way in the cold state of the given substance: after they had once been made luminous by warming, a fresh excitation was necessary before luminosity could be again so produced. Thus heat cannot act as an excitor of phosphorescence, but only as a liberator of light-energy

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already supplied and stored during the lower momentary state. During the upper momentary state, there is, however, no storage of energy. The two momentary states constitute what is sometimes referred to as fluorescence, but, as already stated, it is proposed to restrict this term to gases and liquids in which the duration of the after-glow is at least so short that it has never been measured.

Besides the two momentary and the permanent state, there is a fourth process of lesser importance, on which not much work has been done, to which only passing reference can be made. Lenard found that the shorter ultra-violet rays can excite a luminosity of medium duration falling between that of the momentary and the permanent state; it is most intense in the extreme ultra-violet, and gradually grows fainter with increasing wave-length, becoming unnoticeable in the visible violet. This form of incitation he called the ultra-violet process; it is of account only if the exciting light be of very short wave-length. It has not the definite excitation distribution of the other processes, but seems to be more nearly allied to the permanent than to the momentary states.

In Lenard's researches in conjuntion with Pauli and Kammerlingh Onnes at low temperatures, and subsequent work with improved apparatus, the fact has been clearly established that there are different exciting spectra corresponding to the momentary and permanent bands. These regions of exciting wave-length for the two phases largely overlap, so that in general a given wave-length may induce both processes simultaneously; but some of the shorter wave-lengths of the exciting light induce only the momentary, some of the longer only the permanent process. In Fig. 1 the exciting spectrum corresponding to the momentary process is indicated by the broken line. Thus in the permanent state the energy is at the same time in part stored and in part used for the immediate emission of transformed radiation; but, while that of some wave-lengths is used for both processes, certain small spectral regions are only available for the one process, certain other regions only for the other. By going to a low enough temperature, the three states have been observed in all phosphoroids. Each band stores its own energy, as can be found by observing the exciting spectrum in the lower state.

As regards the exciting spectrum, the character of this for the momentary is somewhat different from that for the permanent state, as can be seen in the figure. The distribution, in the case of the latter, consists of well-defined bands, there being in general more than one exciting band corresponding to each emission band. The most frequent case is that of three sharp, nearly equal maxima of exciting intensity separated by regions in which the light produces no permanent glow. The distribution in the case of the momentary bands is not nearly so sharp; there is only one band of exciting light corresponding to each emission band, and this is ill defined and lies largely in the ultra-violet: the position of the less refrangible edge of the band is characteristic of that band, however.

The theory which Lenard has developed to explain the properties of the bands just described—for the bands are the fundamental things—attributes the phenomena to a photoelectric action[1] of the light, which liberates electrons from the metallic atoms in the "centers" from which the emission of light proceeds present in all phosphorescent substances. These centers are complex molecules having as essential components an atom of the active metal, together with the alkali metal and sulphur, and they are distributed singly and separately throughout the mass of inactive material which forms the bulk of the phosphoroid. They must be fibrous in structure in different directions, as the phosphorescence is destroyed by crushing the phosphoroid. To each emission band must correspond one kind of center, the various kinds functioning independently of one another; as a pure phosphoroid usually shows more than one band, the same active metal and alkaline sulphide must be capable of forming different kinds of center. Again, a single band in a pure phosphoroid has often three definite corresponding bands in the exciting spectrum of the permanent phase (i. e. three wave-lengths particularly capable of exciting it), so that there must be secondary differences among the centers which emit one band, enabling them to resonate to different exciting wave-lengths. Furthermore, each center must be capable of three periods of oscillation, namely, those corresponding to the emission, the excitation, and the extinction by the action of infra-red light to which reference has been made in the introduction, of which details are given later. The centers which Lenard hypothecates to satisfy these conditions are of two kinds, the "momentary" and the "permanent" centers. The permanent centers are systems consisting of atoms of the active metal, the alkali metal and sulphur (say $Ca_x Cu_y S_z$, x, y, z being whole numbers) so arranged that both the metals are held by the valency bonds of the sulphur atom, the difference between the various emission bands which are given by a pure phosphoroid being conditioned by the number of valencies of the active metallic atom by which the connection with the sulphur atom is effected. In support of this view we have the fact that the number of bands is never greater than the number of valencies of the active metal, and that the different bands have widely different intensities, corresponding to a greater facility of formation of certain bondages such as is to be expected. The different excitation bands may correspond to different space arrangements of the metallic atom with respect to the sulphur atom.

The permanent process is most marked in phosphoroids containing sulphur, and hence the assumption is made that in these phosphoroids the sulphur atom is responsible for the storage of the light energy; correspondingly the momentary centers would seem to be free from sulphur. In these, oxygen may very well take the place of sulphur, as oxides containing traces of active metal were long ago shown by Lecoq de Boisbaudran and Crookes to give a phosphorescenee of short duration.

On Lenard's theory the light is emitted by the atom of active metal on the return of an electron previously photoelectrically liberated by the exciting light. In the unexcited state, the atom possesses its normal complement of electrons; in the excited state all the electrons which can be liberated from the atom by the action of light or cathode rays escape from it to other parts of the center; while the intermediate condition, in which the electrons return to the atom, is the occasion of the light-emissions. In the excited state, the escaping electrons are probably stored in the sulphur atom in the case of the sulphide phosphoroids.

The broad bands of which the emitted light is made up are formed by the superposition of spectral lines of varying position, as it may be supposed that the period of the emitted light will vary within limits, both from center to center and from time to time in the same center, in consequence of the variation in the immediate surroundings of the different centers in amorphous substances and the molecular agitation. In support of this view, it has been observed that on decreasing the molecular movements by lowering the temperature of the phosphoroid, the bands become much narrower. By cooling with liquid and soild hydrogen—to about 14 degrees absolute—Lenard and his collaborators have succeeded in getting the bands very sharp: they still remained bands, however, whose intensity would not support a strong dispersion. A line spectrum could, perhaps, hardly be expected even at these low temperatures in amorphous substances, owing to the above-mentioned local variations in the arrangement of the molecules surrounding the centers; there seems more likelihood of such an emission spectrum in crystalline substances. The influence of the immediate surroundings of the centers on the period of the light emitted by them has been beautifully demonstrated in Lenard's experiments on the spectral position of a given emission band in phosphoroids made with sulphides of the different alkali metals. For if similar phosphoroids be prepared with the same active metal, but with different sulphides as bases, we get, passing from one to the other, a series of bands which are in every way analogous to one another, but having maxima which are displaced relatively in such a manner that the wave-lengths of the band maximum, divided by the square-root of the specific inductive capacity of the phosphoroid, gives a number which is roughly constant in all the phosphoroids. But this is what theory says would be the case for a Hertzian electro-magnetic oscillator vibrating in media of different inductive capacities, so that it is to be inferred that the electron which causes the emission of the light vibrates in and has its period controlled by the nature of the immediate surroundings of the atom to which it belongs. This leads to the assumption that the forces which bind the photo-electric electron to its atom extend out so far into the surroundings of the atom that the mean composition of these controls its period; or it may be supposed that the electron moves on the surface of the atom and, in the oscillations which it performs on its return, swings outside the atom while stimulating the emission of light from it—that is to say, from other electrons contained in it. This picture is supported by the results of other experiments on the photo-electric effect.

Very strong confirmation of this view, which attributes the phosphorescence to the photo-electric action of the light on the atoms of active metal in certain "centers" within the phosphoroid, has been obtained in direct experiment on the photo-electric effect in phosphoriod, performed by Lenard in collaboration with Saeland. As phosphoroids are good insulators, as the centers lose negative electricity under the action of light, they acquire a positive charge; finally, they are raised to such a positive potential that the negative electricity can no longer escape. On calculating from the capacity of the phosphorescent sheet and the known initial velocity of the photo-electrically liberated electrons, the charge required to raise the phosphoroid to the necessary potential, it is found that, in order that the positive charge actually acquired may be sufficient to stop the escape of electrons, only a fraction of the surface can be charged by it: this is strongly in favor of the theory that there are certain centers which alone take part both in the phosphorescent and photo-electric action of the phosphoroid. Further, it has been shown by experiment that the two effects are excited by light of the same wave-lengths and that the wave-lengths which are inactive in respect of the one are inactive in respect of the other phenomenon; again, separate components of the phosphoroid which show no phosphorescence also show no photo-electric effect. From the close connection of the two effects, the theory that the photo-electrically liberated electron causes the emission of phosphorescent light seems well established.

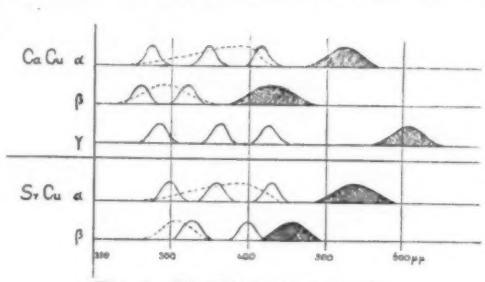

Fig. 1.—Phosphorescence spectra.

J. Becquerel has carried out some very interesting experiments, partly in collaboration with H. Becquerel and Kammerlingh Onnes, on the phosphorescence of uranyl salts. The bands of the spectrum of the emitted light became very narrow at low temperature, but a magnetic field did not appear to influence the emitted light; Lenard had likewise looked for a magnetic effect in the phosphoroids of the alkaline earths and failed to find it. A noteworthy point is that in the uranyl salts no traces of foreign metal condition the phosphorescence, which must be attributed to the uranium itself. Experiment indicates that the "centers" of light emission are present only in relatively very small numbers, as in the phosphoroids hitherto discussed, only a very few of the uranium atoms being active at a time. The experimenters suggest a possible connection between the light-emission and the radioactivity of the uranium atom, the atoms being assumed to be active only while they are breaking down. The fact that the intensity of the emitted light does not decrease when the temperature is lowered even to 14 degrees absolute offers some support to this theory, which is, however, not very strongly upheld.

We now pass on to the extinction of phosphorescence by means of red and infra-red light. The effect, although most marked with red rays, is as a matter of fact not confined to the infra-red region of the spectrum, as Fommel found a short-wave region (384–96 $\mu\mu$) which could also extinguish phosphorescence. Further work by Dahms has shown that light of certain wave-lengths which can extinguish the emission of a phosphoroid already excited can also excite an unexcited phosphoroid, which shows that there is no essential difference between rays which excite and those which extinguish; if light of a given wave-length and intensity falls on a phosphoroid, an equilibrium is finally set up. Thus a piece of spar excited by the ultra-violet showed extinction to the edge of the ultra-violet, but, if previously unexcited, was excited by the whole spectrum up to the infra-red. The experiments of Dahms referred to the whole of the emitted light, as at the time of his work little was known of the separate bands of which this light is made up.

Lenard, studying the effect of infra-red illumination in extinguishing the bands, found that it was in all respects similar to that produced by heat. As already observed by Becquerel, when the phosphoroid is exposed to the extinguishing light, it first of all lights up brilliantly during a short time and then rapidly loses in intensity, the light becoming extinct. The effect of both infra-red light and heating is thus to accelerate the emission of the stored energy and consequently the phosphoroid becomes non-luminous more rapidly. Recent measurements by Lenard have shown that the light-total—the time sum of the light energy emitted as the after-glow of a given band—is the same whatever the rate at which the light is emitted, whether normally or accelerated by heating or irradiation by the red rays. Another example in which the irradiation by the "extinguishing" rays has the same effect as heating the whole phosphoroid is supplied by the effect called by Lenard the "actinodielectric effect." It is found, namely, that if a phosphoroid be subjected to the infra-red rays, its conductivity is temporarily improved, an effect which is also produced by heating the phosphoroid.

After quenching by heat infra-red radiation can produce no further momentary illumination, and *vice versa*. The effect of rise of temperature is to bring out each permanent band as the temperature of the permanent state for that band is reached: the bands then emit very rapidly and die out: if the initial temperature be above that of the permanent state, neither heating nor infra-red produce any effect. The thermometric temperature of the phosphoroid is not appreciably raised by infra-red

[1] The liberation of negative electricity—electrons—which takes place when light of short wave-length falls upon metals and many other substances is called the photo-electric effect.

radiation, but we may assume that the local molecular temperature of the centers rises and that this produces the same effect on the light-emission as heating the whole phosphoroid. The conception of a raised *local* temperature is quite reasonable if we consider the excited centers as resonating to infra-red rays so that they acquire a considerable local kinetic energy. The effect of the local agitation is probably to bring the sulphur atom which stores the electrons emitted from the active metal atom intermittently nearer to the metallic atom, so that the latter "by action at small distances" regains its electrons and so emits its light sooner than it would otherwise have done. The temperature insulation of the centers must be very good, as on cutting off the infra-red radiation its effect continues, just as if the centers remained at their high temperature for some time. If, however, the phosphoroid be first subjected to infra-red radiation and then excited, the preliminary irradiation has no effect on the light-emission, which shows that the period of the excited and unexcited centers is different, the latter not resonating to the infra-red rays. This is as might be expected, as the centers are in a different electrical state in the two cases. An interesting fact is recorded by Pauli, who investigated the ultra-violet and infra-red light emitted by phosphoroids—namely, that no phosphoroid which exhibits a marked and prolonged after-glow ever gives infra-red bands; such bands, if present, presumably accelerate the extinction of the visible bands of the phosphoroid.

The resonating system is probably the oppositely charged or polarized couplet formed by the sulphur atom and the active metallic atom; and the extinction spectrum, which gives the efficacy of the different wave-lengths in accelerating the emission of light, will give by its maximum the free period of the polarized couplet. This accords with the theory of dispersion, which shows that the slowest free periods of the molecules correspond not to vibrating electrons, but to whole atoms or groups of atoms in the molecule, which must be electrically charged or polarized as has been imagined. The experimentally found extinguishing spectrum shows that the extinguishing power has a sharp boundary as we go further into the infra-red. Each active metal seems to have the same distribution in this respect, whatever the alkaline metal of the sulphide, although the distribution of excitation of the different bands is different. This accords well with the hypothesis.

It has been already metioned that Lenard has shown that the total amount of light energy emitted by a given phosphoroid is the same whether the emission be accelerated by heating so as to last only a few seconds or whether it takes place normally. In the same paper he also describes experiments demonstrating that the light total has a limit to which it tends with increasing intensity and duration of excitation; this limit is independent of the nature of the excitation.[1] When this limit is reached the phosphoroid is said to be fully excited by two different wave-lengths separately, and if a band have two different light totals corresponding to these excitations, these light totals are not added together when the phosphoroid is excited by both wave-lengths at once; the emission in this case is of the same intensity as that excited by one alone; this shows that there can only be one kind of center capable of emitting the particular band which can resonate to both exciting periods. While this is true of the permanent bands, the momentary bands, as Hausser has shown, have no limit of emission intensity; in this case the intensity increases steadily with the intensity of excitation, and an addition of the two emissions excited by different wave-lengths is effected when these are used simultaneously.

In comparing the light total caused by excitation by cathode rays and excitation by light, a difficulty arises owing to the fact that the cathode rays cannot penetrate and so excite as thick a layer of the phosphoroid as the light rays: the emitted light increases with the thickness of the phosphorescent sheet used until this is about one millimeter in the case of excitation by light; but with the thinnest sheets which can be prepared the cathode rays already excite their maximum of emitted energy. However, the depth of penetration of the cathode rays can be calculated from their known coefficient of absorption: from such calculations Lenard arrives at the conclusion that the total of emitted light is the same whether the exciting agent be light or cathode rays.

The laws of the decay of intensity of the emitted light were first considered by Becquerel, who, however, investigated the whole of the light emitted from impure phosphoroids and not the separate bands. Since the different bands due to one metal die out at different rates, it is not astonishing that the empirical formula which he proposed represented observation only very roughly. Subsequently Nicholls and Merrit and also Werner put forward as the law of decay of the permanent process the formula $I = \frac{a}{(c + at)^2}$, in which I is the intensity of the light, t the time, and a and c are constants; a formula of this kind had already been used by Becquerel. This seemed to give a fair representation within the observed limits, the time of observation being about thirty minutes. Recently Lenard and Hausser have attacked the problem in great detail and have shown that, inasmuch as according to the conditions of excitation the decay can take place in different ways, so that under certain conditions curves of decay can be obtained for the same band which cut one another, no law can be given without considerable further discussion of the circumstances preceding the after-glow. This is due to a non-homogeneity of the centers, to be mentioned again shortly. They investigate the behavior of the separate bands. Their experiments on the effect of the amount of active metal present in a pure phosphoroid show that the total of emitted light per unit volume of the phosphoroid—the reduction to unit volume follows from experiments made on phosphorescent sheets of different thickness—rises first of all proportionally with the increase of metal in the phosphoroid, but then turns and becomes constant, provided that the phosphoroid be fully excited in all cases. The law of decay, and therefore to some extent the light total, depends upon the amount of excitation, if this be insufficient to excite the phosphoroid fully: the first falling off in intensity is relatively greater for a brief excitation. These and other observations lead to the assumption of the simultaneous presence of permanent centers of different duration: those of small duration will be quickly excited and will quickly decay, while the more durable will have a slow excitation corresponding to their slow falling off. This assumption accounts for the observed influence of the duration of the excitation on the law of decay, as in the case of brief excitation a relatively much larger number of quickly decaying centers are excited than by a longer excitation. As regards the amount of metal present, if this be small, only more permanent centers are formed in the phosphoroid; as it is increased, the number of such centers increases until a stage is reached when all that are possible are formed, and then the less persistent "permanent" centers are produced. After this, the addition of active metal does not increase the number of permanent centers, as experiment shows. The metal then goes to form "momentary" centers, the intensity of the momentary process being exceedingly small for small metal content. Hirsh has shown that for a large number of bands the intensity of the momentary process continually increases with the amount of active metal, while, as stated, the number of permanent centers soon reaches a limit. He has also shown that a higher temperature is needed to prepare phosphoroids of pronounced after-glow, which falls in with the hypothesis, as other considerations show that the centers of long duration must be very large atomic complexes which would take some time to form, the production of which would accordingly be much facilitated by the increased diffusion consequent on a higher temperature in the preparation. Short heating at comparatively low temperature will give rise to a phosphoroid which shows a good momentary process and only a very faint permanent process.

[1] Which may be light or cathode rays.

The Presence of Boron in Milk and in Eggs

THE researches that Messrs. Gabriel Bertrand and H. Agulhon of the Pasteur Institute have already published concerning the presence of boron in the human organism, have demonstrated that, contrary to what had been sustained formerly, not only this metalloid exists in the animal organism as well as in vegetables, but moreover there is every reason to suppose and admit its normal presence in every degree of the zoological scale.

Following on these results, the same authors have come to think that boron may perhaps be of a fundamental element of the living cellule, if, like iron and magnesia, it plays an indispensable part in nutrition exchanges. This question has led them to complete their statical researches by the examination of milk and of birds' eggs. The fact is there is some reason to suppose that if boron really possesses a cellulary importance, it must already exist in the first stages of life; that it must consequently exist in milk—that liquid that has to supply in itself alone, for a considerable period, all the alimentary requirements of the young mammifer. Likewise, boron must also be found in eggs, that is to say, in a state of development in which it is not necessary to take into consideration the contamination of the organism by exterior contributions.

Now, concerning four species of milk (woman's, ass's, goat's, cow's) collected in the presence of the above-named authors, into vessels cleaned by them, the immediate research for boron each time gave them distinct results.

They have likewise discovered the presence of boron in birds' eggs. So they conclude that in all probability boron is to be classed along with other catalytic elements of the living cell.—*The Chemical News.*

The Subterraneous Waters of Egypt

DR. ROUX, the Director of the Pasteur Institute, has lately communicated to the Academy of Sciences a very interesting work of M. Audebean Bey, concerning the subterraneous waters of Egypt. This study gives a classification of the grounds from the point of view of their permeability.

The Chief Engineer of the Egyptian State Domains explains the differences that are remarked in the permeability of the soil in the valley of the Nile, by the deposits of various sorts, due to the divagations of the sinuosities of the branches of the river and of the natural canals during the pleistocene period, and by the changes effected in the dykes and the breaches of the ancient inundation basins in the course of the centuries during which lasted the system of submersion of flooding, etc.

M. Audebean Bey shows that with the works of mechanical draining, which are at present being undertaken in the North of Delta, it will be possible to give to the soil in that region, to-day waste and uncultivated, the fertility it possessed during the Grecian-Roman period, and perhaps even that of the most remote times. He adds also that when the time has arrived, it will be easy to drain and dry the lakes that lie along the Mediterranean coast and to cultivate the vast superficies they occupy.—*The Chemical News.*

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